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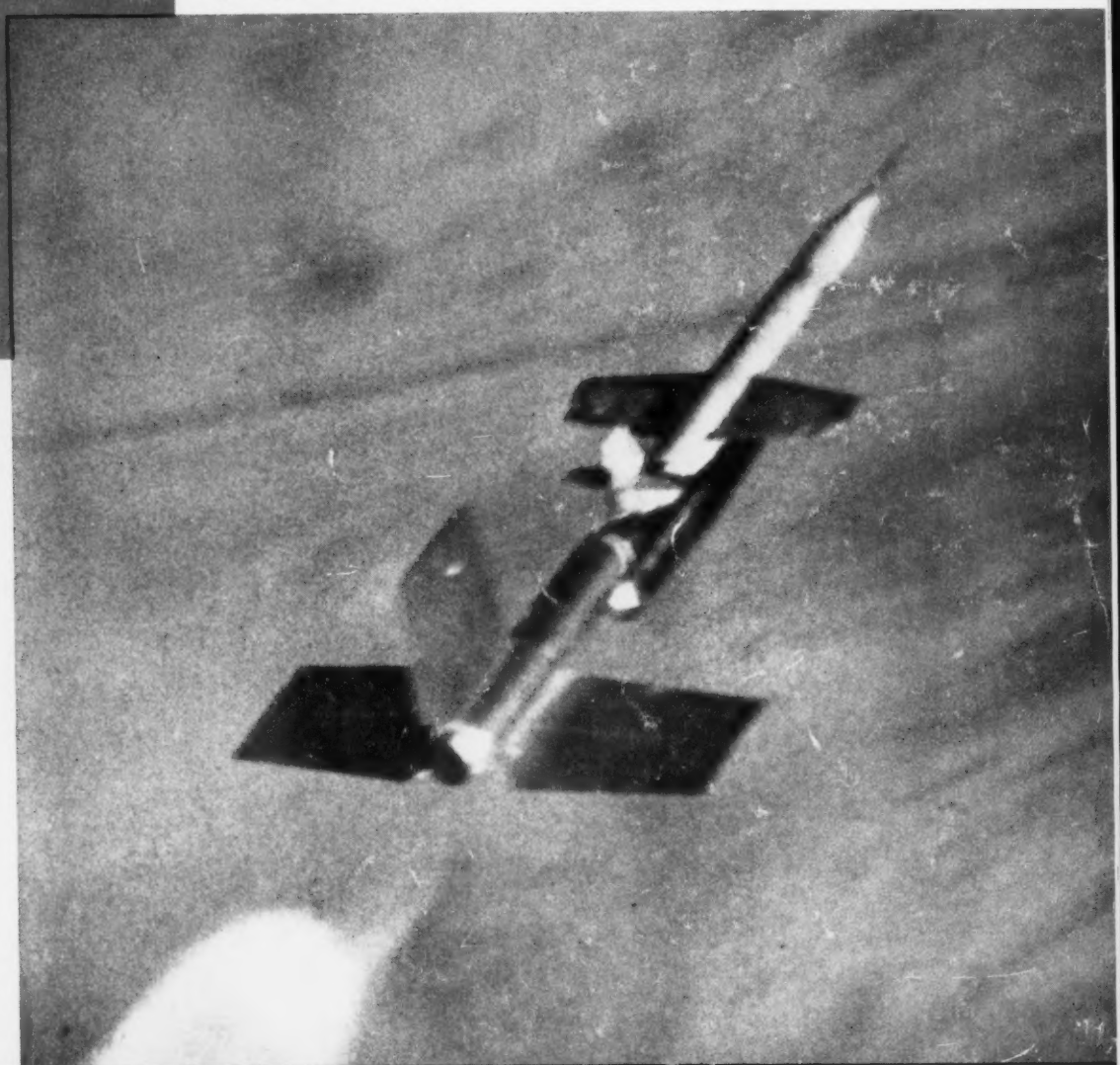

research • design • construction • testing • operation

Zero to Infinity

. . . an editorial

December, 1957

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Aeronautical Engineering Review

Vol. 16—No. 12 December, 1957

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Cover—Lockheed Aircraft Corporation reports its ram-jet missile X-7 has set three speed records—for a ram-jet, for any ground-controlled missile, and for any recoverable missile—during its tenth flight. The firm's Missile Systems Division says the X-7 is launched from a B-29 and powered by a rocket booster to a speed where the ram-jet takes over. Each parachute recovery saves $350,000, according to the firm. The missile is used for testing ram-jet engines and other components.

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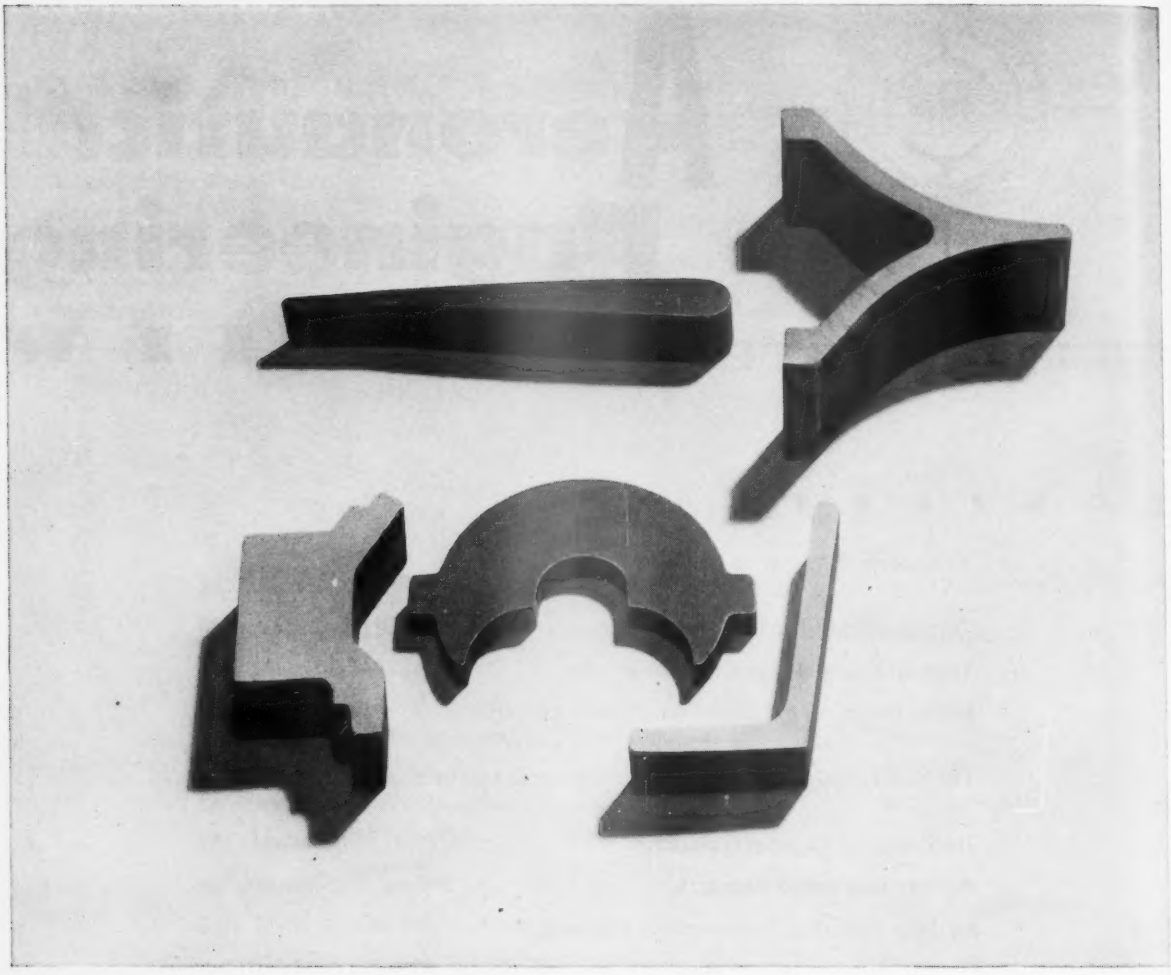

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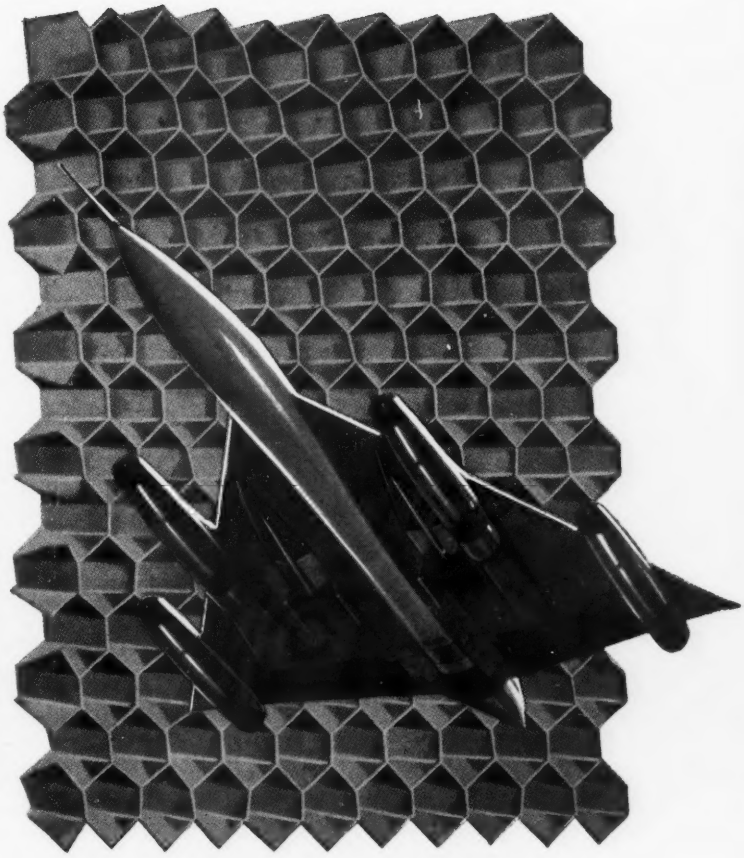

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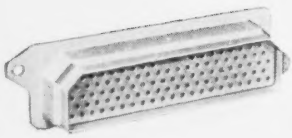

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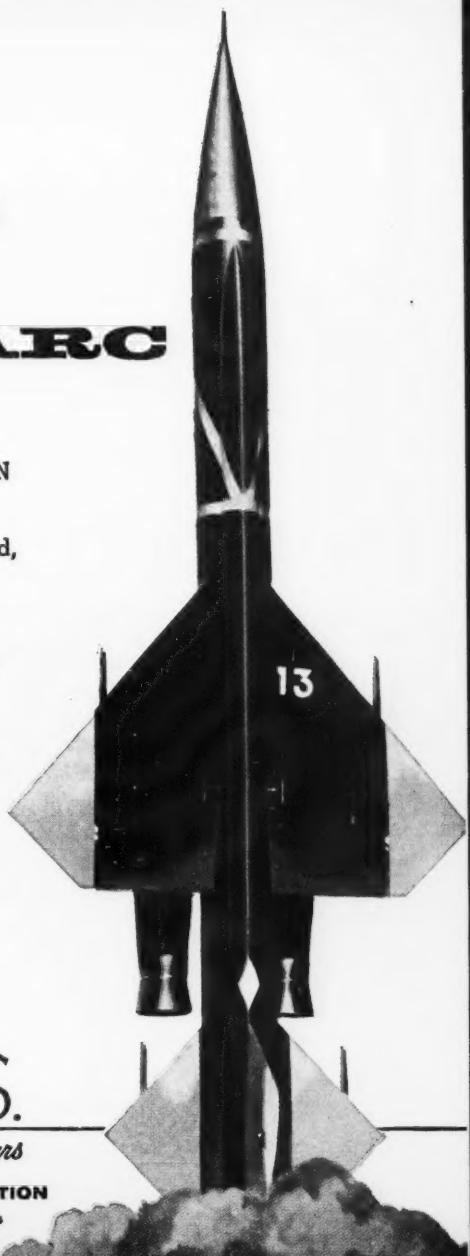

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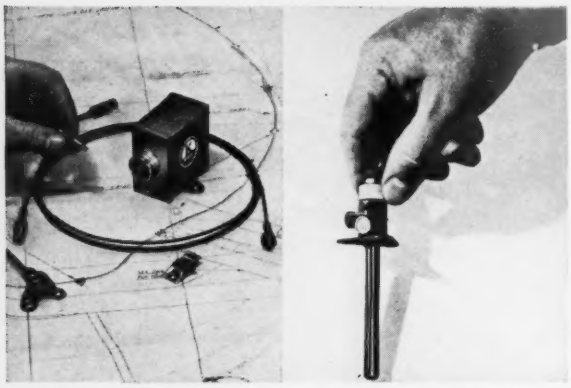

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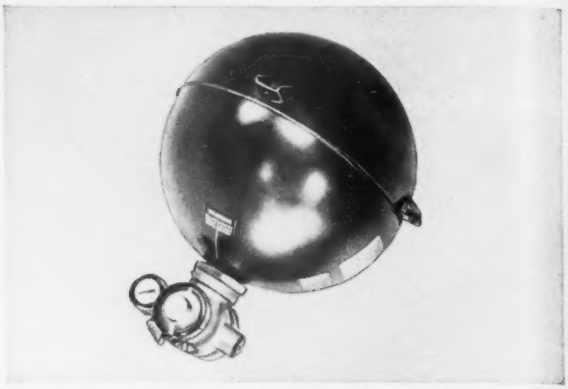

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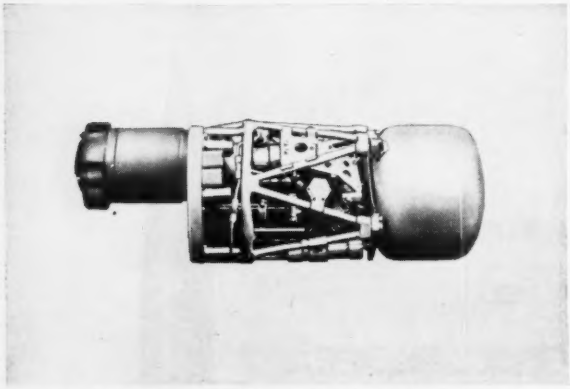

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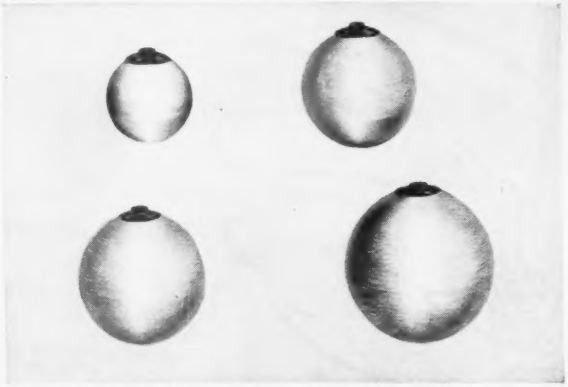

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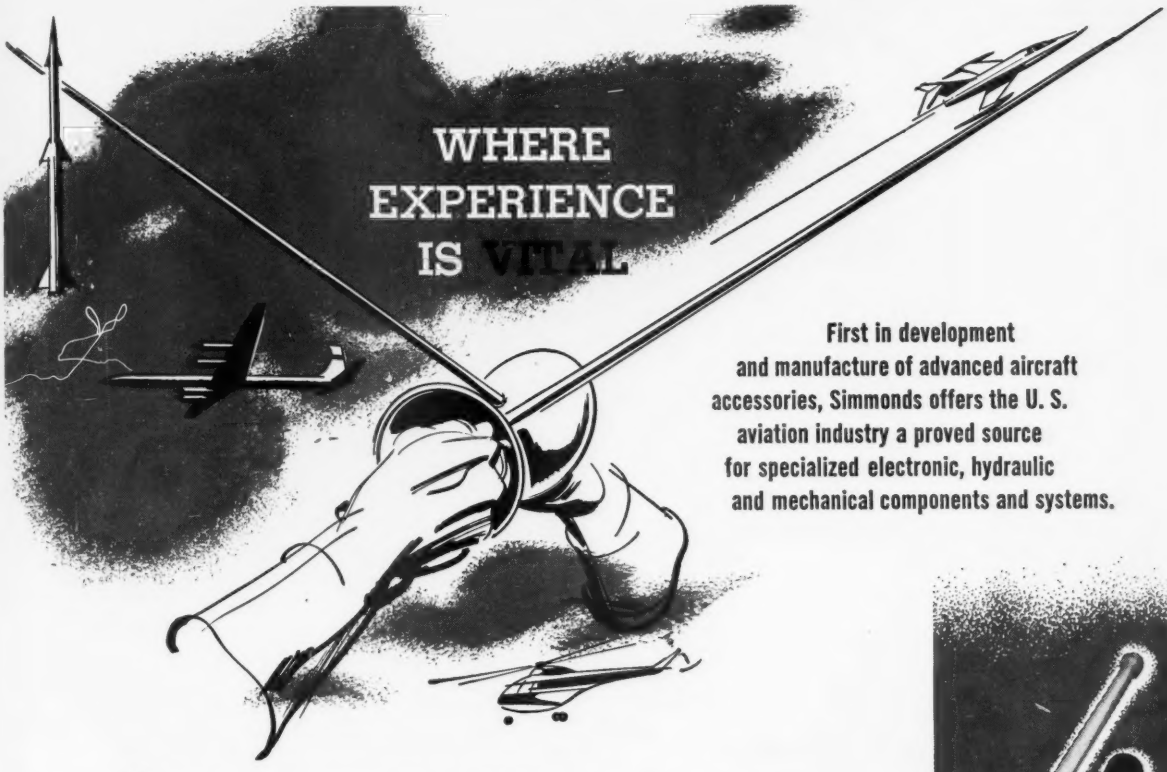

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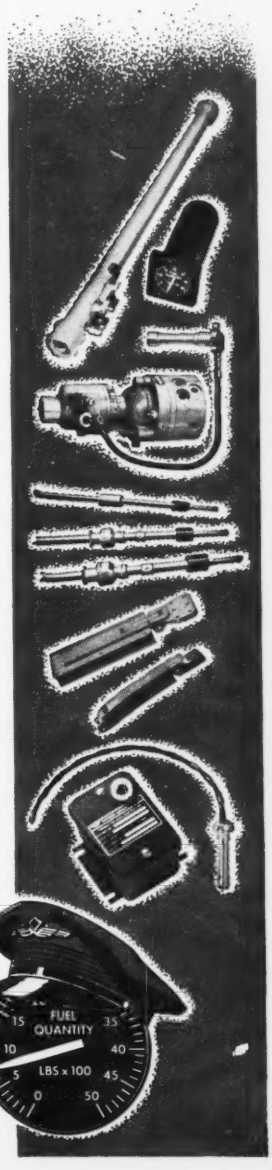

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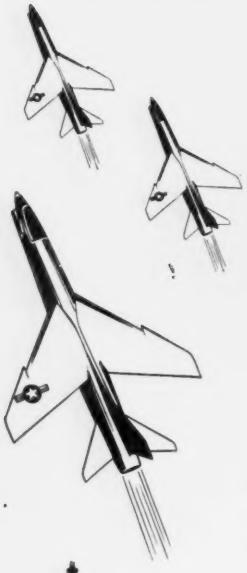

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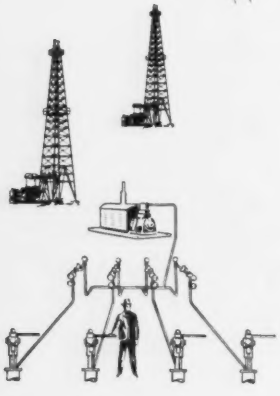

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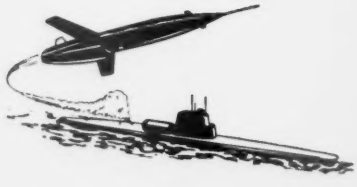

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IAS News Notes

December 1957

NEW IAS PRESIDENT for 1958 is EDWARD C. WELLS, a Fellow of the Institute and Vice-President - Engineering, Boeing Airplane Company. He will take office at the Honors Night Dinner. Also elected by the Council are four new IAS Vice-Presidents: Neil Burgess, General Electric Company; General B. W. Chidlaw, USAF (Ret.), Thompson Products, Inc.; L. Eugene Root, Lockheed Aircraft Corporation; and H.Guyford Stever, Massachusetts Institute of Technology.

MISSILES AND SPACE TECHNOLOGY, playing the featured role in this year's IAS Annual Meeting, should draw large audiences among the technical sessions. The most stimulating discussion probably will occur during the Missile Development session - the Army, Navy, and Air Force will present papers on this subject in the same session.

ANNUAL STUDENT CONFERENCES for 1958 are shaping up rapidly. Two dates already have been established - the Indianapolis Regional Conference will take place on April 7; the Northeastern Regional Conference is scheduled for March 22 at Stevens Institute of Technology, Hoboken, New Jersey.

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PROMOTIONS AND HONORS: Donald W. Douglas, Jr. (AF), has been elected President of Douglas Aircraft Company, Inc. The Senior Douglas remains Board Chairman and chief executive of the firm. James H. Doolittle (HF) and Clifford C. Furnas (F) have been awarded Honorary Doctor of Engineering degrees by the University of Michigan. Major General Albert C. Boyd (F), 1955 Chanute Award winner, has retired from the Air Force.

NATIONAL MEETINGS CALENDAR

Dec. 17	Wright Brothers Lecture, Natural History Building Auditorium, Smithsonian Institution, Washington, D. C. "Hypersonic Flight and the Re-Entry Problem" by H. Julian Allen.
1958	
Jan. 27-30	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.
Mar. 13-14	Flight Propulsion Meeting (Classified), Hotel Carter, Cleveland.
May 12-14	National Midwestern Meeting on Guided Missiles, Hotel Chase, St. Louis, Missouri.
July 8-11	National Summer Meeting, Los Angeles, California.
Sept. 8-13	First International Congress, International Council of the Aeronautical Sciences, Palace Hotel, Madrid, Spain.

JOINT MEETINGS CALENDAR

Mar. 17-21 1958 Nuclear Congress, International Amphitheatre, Chicago. Coordinated by Engineers Joint Council.

June 2-4 National Telemetering Conference, Lord Baltimore Hotel, Baltimore, Maryland. Sponsored by IAS, ARS, ISA and AIEE.

June 19-21 1958 Heat Transfer and Fluid Mechanics Institute, University of California, Berkeley, Cosponsored by IAS.

SECTION MEETINGS CALENDAR

Dec. 3 Rocky Mountain Section: Dinner Meeting in conjunction with IAS Student Branch, University of Colorado (Social at 6, dinner at 6:30), Town House, E. Colfax Ave. and Peoria Street, Aurora. "Escape From High-Speed Aircraft" by R. H. Frost.

Dec. 4 Philadelphia Section: Dinner Meeting, Philadelphia International Airport, Skyview Dining Room. (Social hour sponsored by TWA at 6:30, dinner at 7.) "Some Factors in the Jet Transport Picture" by N. R. Parmet.

Dec. 7 Texas Section: Field trip, Chance Vought low-speed wind tunnel, Dallas, 9:30 a.m.

Dec. 9 Indianapolis Section: Tour of CAA Tech. Development Center, Indianapolis, 7 p.m. Donald M. Stuart is host.

Dec. 10 Los Angeles Section: Specialist Meeting, IAS Building, 7:30 p.m. "High-Temperature Effects in Structures" by N. J. Hoff.

Dec. 10 Tulsa Section: Dinner Meeting and Field Trip, Douglas Aircraft Co., Inc., Electronics Lab. Dinner at 6:30, tour at 7:30.

Dec. 10 Hagerstown Section: Specialist Meeting, Washington County Museum of Fine Arts, 7:30 p.m. "The F-27 - Part II. Panel Presentation on Engines, Fuel System, Air Conditioning, and Pressurization." Robert O. Snyder, Chairman.

Dec. 11 Chicago Section: Dinner Meeting, Glenview Naval Air Station, 6:30 p.m. "Water-Based Aircraft - The Martin SeaMaster and SeaMistress" by Guy Mallery.

Dec. 12 Atlanta Section: Dinner Meeting, U. S. Naval Air Station, 7:30 p.m. "Army Airmobility Requirements" by Brig. Gen. Edward Tucker.

Dec. 12 Tullahoma Section: Specialist Meeting, 7:30 p.m. (place to be announced). "Some Aspects of Nuclear Flight" by R. A. Thompson.

Dec. 19 Texas Section: Specialist Meeting, 8 p.m. (place to be announced). "Hypersonic Flight and the Re-Entry Problem" by H. Julian Allen.

Jan. 15 Texas Section: Specialist Meeting, Arlington State College, Arlington, Texas, 8 p.m. "Boundary-Layer Control" (speaker to be announced.)

N

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IAS News

A Record of People and Events of Interest to Institute Members

Missile, Satellite, Gravity Sessions Scheduled for IAS 26th Annual Meeting

MORE THAN 2,500 aeronautical scientists, engineers, and technicians will convene in New York for the Twenty-Sixth Annual Meeting of the Institute of the Aeronautical Sciences. The conference will be held at the Sheraton-Astor Hotel, January 27–30, 1958.

Four ballrooms will be in use when some 25 technical sessions are conducted during the 4-day program. Sessions on missiles, earth satellites, gravity, and space propulsion are expected to highlight the conference, marking the beginning of the IAS second quarter century. (At last year's Silver Anniversary meeting, 97 technical papers, panel discussions, and special reports were grouped in 25 sessions.)

More than one session has been arranged to cover certain fields of interest. Sessions will be held simultaneously to present as much information as possible.

W. Stuart Symington, U.S. Senator from Missouri and former Secretary of the Air Force (1947–1950), will be the principal speaker at the Honors Night Dinner on Tuesday, January 28.

Mundy I. Peale, retiring IAS President, will be Toastmaster at the Honors Night Dinner. He will present the John Jeffries, Robert M. Losey, Sylvanus Albert Reed, Lawrence Sperry, and Grover E. Bell awards and announce the election of Honorary Fellows and Fellows, both American and foreign, for 1957.

Session Chairmen

Organizer and Chairman of the Earth Satellites session is Joseph Kaplan (AF), Professor of Physics, University of California, and Chairman, National Committee for the IGY.

Of four sessions on Aerodynamics, one titled Hypersonic Aerodynamics will be headed by William R. Sears (F), Director, Graduate School of Aeronautical Engineering, Cornell University. Another will cover Propulsion Aerodynamics and a third, Design Aerodynamics.

Missile and missile applications, to have a major share of the meeting, will be represented in a session on Missile Development, organized by Abe Silverstein (F), Associate Director, NACA Lewis Flight Propulsion Laboratory; a session on Missile Guidance; and an Electronics session on Early Warning Systems.

Chairman and organizer of the Gravity Session is Charles Tilgner, Jr. (AF), Chief Aeronautical Engineer, Grumman Aircraft Engineering Corporation.

An Aeroelasticity session is being headed by Alexander Flax (M), Assistant Director, Technology, Cornell Aeronautical Laboratory, Inc.

A session on Flight Safety is being organized by Jerome Lederer (F), Director, Flight Safety Foundation, Cornell-Guggenheim Aviation Safety Center. Dr. Lederer also is Chairman of this session.

Sessions on Rotary Wing Aircraft Dynamics and Rotary Wing Aircraft Design will be headed by Robert Loewy (M) and Robert Wagner, respectively. Mr. Loewy is Chief Dynamics Engineer, Vertol Aircraft Corporation. Mr. Wagner is Chief Engineer, Hiller Helicopters.

Major Gen. Otis O. Benson, Jr., USAF (MC), School of Aviation Medicine, Randolph AFB, is Chairman of the Aero Medicine session.

Chairman of a session on Air Traffic Control will be David D. Thomas (M), Director, Office of Air Traffic Control, CAA.

Rear Adm. Luis de Florez (F), USN (Ret.), Consulting Engineer, is Chairman of a session on Human Factors: Instrumentation Simplification.

A session on VTOL/STOL Aircraft will be headed by Capt. Sydney S. Sherby (AF), USN, Office of Naval Research.

W. Stuart Symington

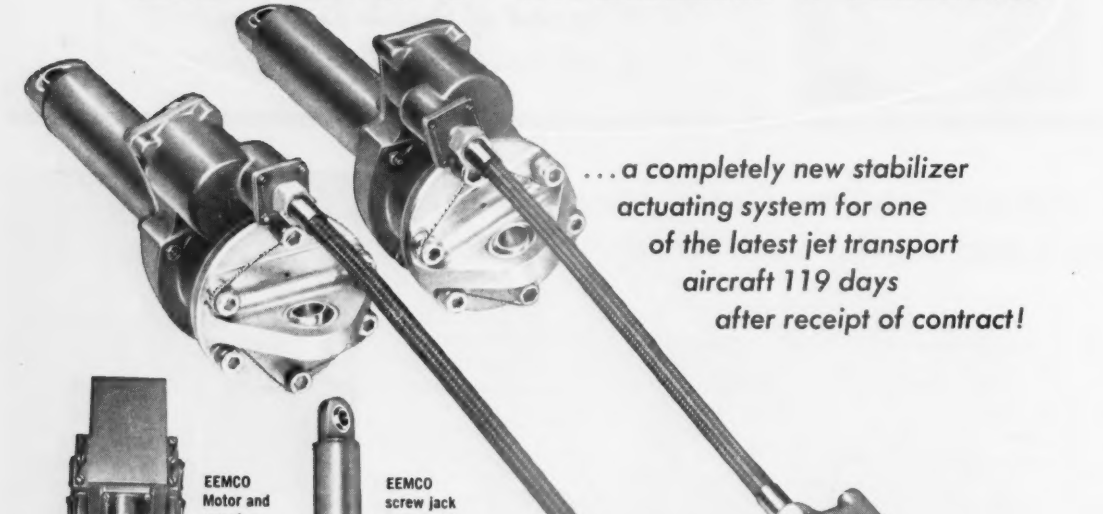
Major Vincent Haneman, Jr. (AF), USAF, Associate Professor of Aeronautical Engineering, Wright-Patterson AFB, is Chairman of a session on Education.

One of three sessions on Structures will be headed by Walter Ramberg (AF), Chief, Mechanics Division, National Bureau of Standards. Structures—High Temperature Effects and Missile Structures comprise two of the sessions.

Management Panel

A panel discussion, Engineering Management—Long-Range Planning, has been organized by Edward A. Ledeen (M), Manager, Component Operations, Wright Aeronautical Division, Curtiss-Wright Corporation. Panel members will be W. B. O'Neal (M), Vice-President, Hayes Aircraft Corporation; Garrett C. Covington (AF), Vice-President—General Engineering, McDonnell Aircraft Corporation; R. L. Bortner (AF), Chief Engineer—Administration, Republic Aviation Corporation; and William G. Purdy (M), Director, Systems Development Division, The Martin Company. Panel Moderator will be Joel M. Jacobson (AF), Vice-President and General Manager, Aircraft Armaments, Inc.

EEMCO DELIVERS



...a completely new stabilizer actuating system for one of the latest jet transport aircraft 119 days after receipt of contract!

EEMCO Motor and gear box Type D-981

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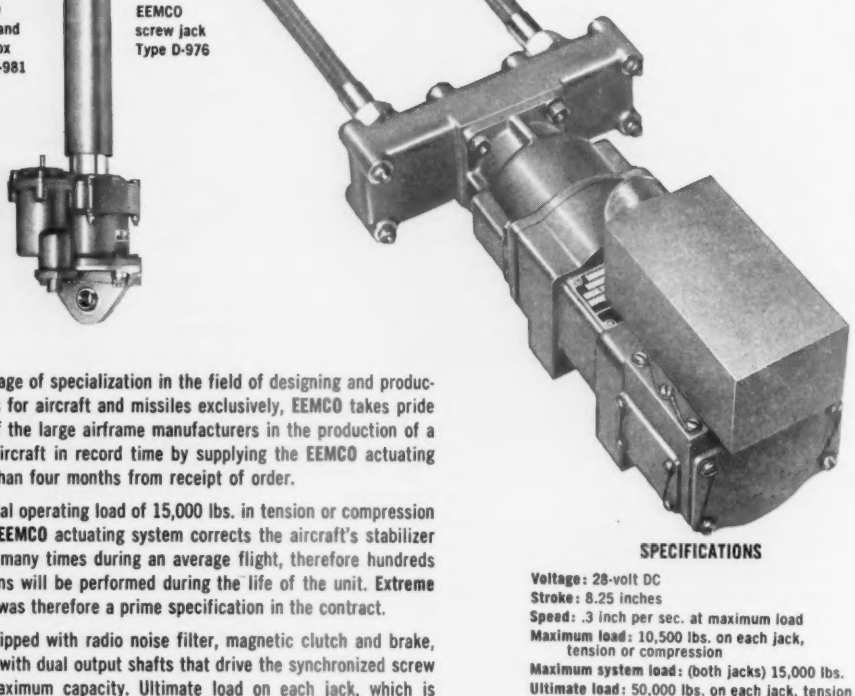

Again proving the advantage of specialization in the field of designing and producing actuators and motors for aircraft and missiles exclusively, **EEMCO** takes pride in having assisted one of the large airframe manufacturers in the production of a new type jet transport aircraft in record time by supplying the **EEMCO** actuating system illustrated less than four months from receipt of order.

Capable of handling a total operating load of 15,000 lbs. in tension or compression on both jacks, this new **EEMCO** actuating system corrects the aircraft's stabilizer in flight. It will operate many times during an average flight, therefore hundreds of thousands of operations will be performed during the life of the unit. **Extreme reliability** of the system was therefore a prime specification in the contract.

The 28-volt motor is equipped with radio noise filter, magnetic clutch and brake, and an integral gear box with dual output shafts that drive the synchronized screw jacks at loads up to maximum capacity. Ultimate load on each jack, which is equipped with non-jamming stops, is 50,000 lbs. tension or compression. The jacks, with a stroke of 8.25 inches at .3 inch per second at maximum load (15,000 lbs.), are equipped with an auxiliary reduction for a control mechanism.

The proven elements of this efficient **EEMCO** actuator system, motor with gear box and the jacks, can be adapted for other uses individually or in similar assemblies.

Your inquiry is invited.

SPECIFICATIONS

Voltage: 28-volt DC
Stroke: 8.25 inches
Speed: .3 inch per sec. at maximum load
Maximum load: 10,500 lbs. on each jack, tension or compression
Maximum system load: (both jacks) 15,000 lbs.
Ultimate load: 50,000 lbs. on each jack, tension or compression — 100,000 lbs. total
Military Specs: Assembly designed to meet MIL-M-8609, MIL-A-8064 and MIL-E-5272A
Features:
1. Jacks are equipped with non-jamming stops.
2. Single power unit drives the jacks at synchronized speed.
3. Jacks are equipped with auxiliary reduction for a control mechanism.
4. Motor has magnetic clutch and brake.

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Career Development Booklet For IAS Corporate Members

The IAS Engineering Career Development Committee has announced publication of a handbook for Corporate Members designed to provide source information for development and improvement of educational aid programs.

The handbook has been prepared in loose-leaf form with a binder, with individual sections prepared by separate subcommittees. These are in the following categories: background data, youth motivation, aid at the primary and secondary school levels, and aid at the college and university level.

In addition, the sections contain summaries of current activities of all Corporate Members and other major representative industries. A bibliography of current literature, periodicals, and active organizations in the technical manpower improvement field also has been provided.

The ECDC was created as a result of the 1955 West Coast Industry-Faculty Conference to study means of improving aircraft industry educational efforts.

Necrology

Harold Gatty

The Institute has received word of the death of Harold Gatty (AF) at Suva, Fiji Islands, on August 29. He was 54.

Mr. Gatty flew around the world with Wiley Post in 1931 in the Lockheed Vega "Winnie Mae" and later collaborated with Post to write *Around the World in Eight Days*. He also wrote *The Raft*, an ocean survival handbook which was adopted by the USAF.

Mr. Gatty founded an air navigators school at Los Angeles, Calif., and had designed several navigation instruments. Later, he headed the USAF navigator research and training. He also contributed to planning Pan American Airways' trans-Pacific routes.

A native of Tasmania, he served in the New Zealand and Australian Merchant Navy. He also served in the RAAF during World War II and was later Director of Training, USAAF, in Australia.

He formed Fiji Airways after the war and just before his death had completed a book on the value of natural observation in air navigation.

Comdr. Jack J. Tomamichel USN (Ret.)

News of the death of Comdr. Jack J. Tomamichel, USN (Ret.) (M), on June 24, has reached the Institute. He was 47.

Commander Tomamichel had been an aeronautical engineer and Navy pilot. He learned to fly as a Navy Student Aviator at Pensacola, Fla., in 1935, after serving as a Naval officer on battleships for 2 years. From 1936 to 1939, he was a pilot in VF Squadrons assigned to the U.S.S. "Langley," U.S.S. "Lexington," and U.S.S. "Enterprise."

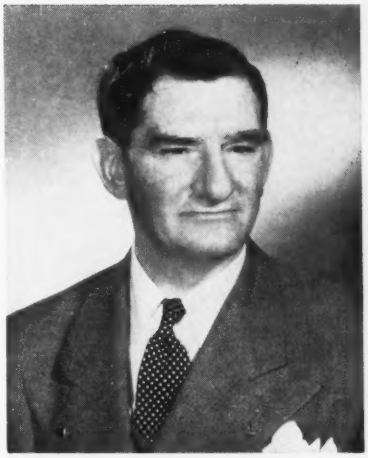
He received a degree in aeronautical engineering from the California Institute of Technology in 1942 and served as a Technical Officer (Aero) from 1942–1945 in the South and Central Pacific theaters. In 1945 he was named Superintendent, Aeronautical Materials Laboratory, Philadelphia, Pa. As a pilot he had accumulated 3,000 hours in all types of Navy aircraft.

Edgar Schmued Forms Own R&D Firm

Edgar Schmued, a Fellow of the Institute and REVIEW Editorial Adviser, has resigned from full-time duties as Corporate Vice-President—Technical, Northrop Aircraft, Inc., to form his own research and development organization.

Mr. Schmued will continue his association with Northrop as a consultant. His new firm will devote a large portion of its efforts toward military defense work. The firm also will be diversified with substantial work on commercial projects not confined to the aircraft field.

A native of Hornsbach, Bavaria, Mr. Schmued came to the United States in 1930 and is credited with many notable contributions to American air power. He began his aeronautical career during World War I and developed numerous advanced-design aircraft and weapons systems during World War II and the Korean War.



Edgar Schmued

Brooklyn Polytechnic Names Ferri Department Head

Antonio Ferri (F), director of a Mach 14 wind tunnel and designer of the air scoops on the F-105, has been named Head, Aeronautical Engineering Department, Polytechnic Institute of Brooklyn.

Before World War II, Dr. Ferri was head of the supersonic wind tunnel at Guidonia, Italy, where later the world's first jet plane (Campini) was designed. An underground fighter during the war, he was brought to the United States in 1944 and assigned to NACA's Langley Laboratory.

Dr. Ferri joined Brooklyn Polytechnic in 1951 to found the special aerodynamics laboratory he now heads at Freeport, N.Y. He is currently performing ICBM research at this facility which contains two supersonic and two hypersonic wind tunnels.

He is also a member of the Academy of Science of Turin and U.S. Representative to AGARD's Combustion and Propulsion Panel.

NEWS OF MEMBERS

▶ **Anshal I. Neihouse** (AF), Head, Langley Aeronautical Laboratory Spin Tunnel, has been awarded the NACA Exceptional Service Medal for outstanding leadership in the development of spin research techniques and the art of predicting spin and recovery characteristics of aircraft.

▶ **John B. Parkinson** (M), Chief, Hydrodynamics Research Division, NACA Langley Aeronautical Laboratory, has been awarded the NACA Exceptional Service Medal for his analysis and experimental verification of the principle that high length-beam ratios improve hydrodynamic and aerodynamic characteristics of seaplane hulls. Mr. Parkinson was awarded the first IAS Water-Based Aviation Award earlier this year.

▶ **Charles H. E. Warren** (AF), Principal Scientific Officer, Aerodynamics Department, Royal Aircraft Establishment, Farnborough, has been awarded a Commonwealth Fund Fellowship and will be at the Guggenheim Aeronautical Laboratory, California Institute of Technology, for the 1957–1958 academic year.

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Alfred Africano (M), formerly Head, Power Plant Design Department, Chrysler Missile Operations, Detroit, Mich., has joined the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif.

James R. Anderson (A), formerly East Coast Sales Engineer, National Water Lift Division, Cleveland Pneumatic Tool

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Co., has joined Thompson Products, Inc., as Eastern District Sales Manager.

R. Harvey Anselm (M) has been named new manager of Beech Aircraft Corporation's Missile Engineering Division. He formerly served as Project Engineer and Weapon Requirements Engineer in the design, production, and testing of missile articles and remote-controlled target aircraft under Beech development.

Lt. Col. Melville W. Beardsley (M), USAF, formerly Programing Officer, Directorate of Research and Development (Pentagon), has been reassigned to ARDC Headquarters as Director of Aeronautics.

Samuel M. Berkowitz (AF), formerly with Franklin Institute Laboratories for Research and Development, has joined Philco Corporation's Government and Industrial Division as Executive Engineer in Air Traffic Control.

William O. Boschen (A), Vice-President of Avien, Inc., has been named General Manager for the firm. Before joining Avien 3 years ago, he was Eastern Regional Manager of Minneapolis-Honeywell's Aeronautical Division.

R. A. C. Brie (AF) has joined the Technical Department, Westland Aircraft Limited, Yeovil, Somerset, U.K. His former position was Official-in-Charge, Helicopter Experimental Unit, British European Airways Corporation.

Frederick C. Durant, III, (AF), has been named Executive Assistant to the Director, Avco Research Laboratory, Research and Advanced Development Division, Avco Manufacturing Corporation. Mr. Durant had been a staff member of Arthur D. Little, Inc.

J. Elmo Farmer (M), formerly Technical Assistant, Allison Division, General Motors Corporation, is now an Aeronautical Power-Plant Research Engineer in the Propulsion Systems Division, Lewis Flight Propulsion Laboratory, NACA.

Marjorie Hecht (M), formerly with Vertol Aircraft Corporation, has joined Kaman Aircraft Corporation as a design engineer.

C. G. Holschuh (M), President and General Manager, Sperry Gyroscope Company, Division of Sperry Rand Corporation, has been elected a Director of the corporation by the Board of Directors.

Comdr. H. J. Huester (AF), USNR, has been transferred from Jacksonville NAS where he was Aeronautical Engineering Officer to a new post as Deputy Director, Aeronautical Structures Laboratory, NAMATCEN, Philadelphia, Pa.

George Kass (AF), who was Assistant Senior Project Engineer, Stratos Division, Fairchild Engine and Airplane Corporation, has joined Airborne Instruments Laboratory, Inc., Engineering and Production Division, as Staff Engineer, Mechanical Design.

Lester G. Kelso (M), formerly Development Engineer, United Air Lines, Inc., has joined Boeing Airplane Company as Group Engineer, Preliminary Design, Transport Division.

Theodore W. Knacke (M), formerly Technical Director, USAF 6511th Test Group NAAS, El Centro, Calif., has joined Aeronautical Equipment Research Corporation, A Division of M. Steinthal & Co., Inc., as Chief Engineer, West Coast Division, El Segundo, Calif.

Milton Lief (M), Vice-President-Manufacturing, American Fixture, Inc., St. Louis, Mo., has joined Cupples Products Corporation as Plant Manager in charge of all production.

Charles H. Lutz (M), formerly head of design and development of stabilized platforms at Arma Division, American Bosch Arma Corporation, has joined United Aircraft Corporation, Hamilton Standard Division as Chief, Advanced Design, Electronics Department.

Frank E. Marble (M) has been promoted from Associate Professor to Professor, Jet Propulsion and Mechanical Engineering, California Institute of Technology.

Erik Mollo-Christensen (M), on a leave of absence from Massachusetts Institute of Technology where he is Assistant Professor of Aeronautical Engineering, has been appointed a Senior Research Fellow in aeronautics at California Institute of Technology.

Robert H. Page (M), formerly Research Analyst, Esso Research and Engineering, Linden, N.J., has accepted a professorship in the Mechanical Engineering Department at Stevens Institute of Technology, Hoboken, N.J.

Edward Pepper (AF) has joined The Ramo-Wooldridge Corporation as a WS-315A Program Engineer. He formerly was Project Engineer, Johnsville Naval Air Development Center.

Robert Rautenstrauch (A) has resigned his position as Research Engineer, Curtiss-Wright Research Division to join Thompson Products, Inc., Jet Division as Technical Supervisor in Structures and Process Development.

S. R. Sartore (AF), former Manager, Bell Aircraft Corporation, X-1A, X-1B, and X-2 Test Programs at Edwards AFB, has joined Lockheed Aircraft Corporation's Missile Systems Division as Manager, Airborne Systems Department, Sunnyvale, Calif.

Carl F. Schory (M), after 27 years as Service Manager, Hamilton Standard Division, United Aircraft Corporation, was officially retired September 30 and then named Assistant to the General Manager.

C. H. E. Warren (AF), on leave from his position as Senior Member, Scientific Staff, the Royal Air Force Establishment, U.K., has been appointed a Senior Research Fellow in aeronautics at California Institute of Technology.

CORPORATE MEMBER NEWS

• **Aeroquip Corporation** reports that its 601 Lightweight Engine Hose and 624 Fireproof Sleaving installed in an Aero Commander 680–S have exceeded CAA requirements, giving three times the service life of the original hose application. The firm has published an engineering bulletin on the Aeroquip Hydrauliscope giving technical data and other information. Write to the firm's Advertising Department, Jackson, Mich., for a copy of Industrial Engineering Bulletin No. 24. John C. Abbey has been appointed Chief Engineer, Jackson Engineering Department, to direct all development engineering activities.

• **Allis-Chalmers Manufacturing Company** has announced a new line of motor starters reported to be 2,300 to 4,160-volt Type H for full or reduced voltage starting, reversing or nonreversing, dynamic braking or multispeed control of squirrel-cage, and synchronous or wound rotor motors. Allis-Chalmers International has been formed as a major operating division.

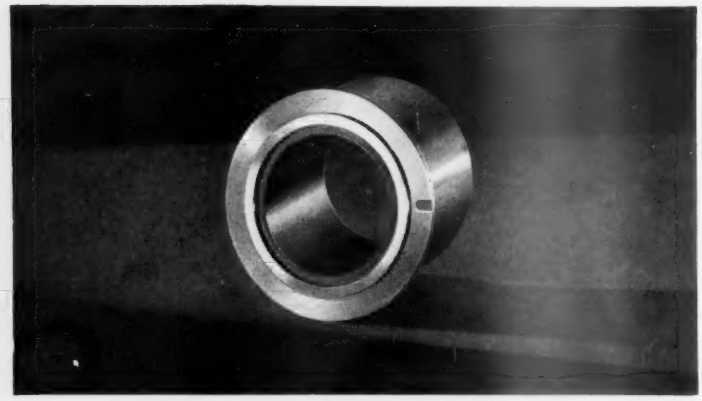
• **Allison Division, General Motors Corporation** conducted an around-the-clock demonstration of its prop-jet engines and Aeroproducts Turbo-propellers in October according to the firm. A military version of the Convair 340 was used as the test aircraft to provide engine and propeller flight-operating data to the military, commercial operators, and airframe manufacturers. Allison model 501-013 prop-jet engine to be used in the Lockheed Electra has been certified by the CAA.

• **Aluminum Company of America** has made a new aluminum-lithium alloy for aircraft structures said to withstand temperatures up to 400°F. The firm reports the rare earth produces the effect of increasing the modulus of elasticity of aluminum alloys. The alloy is designated X2020. Alcoa also has announced the installation of four aluminum sand castings, said to be the largest such assembly ever cast, in the heavy machining department of North American Aviation, Inc. Weighing more than 12.5 tons, it will become part of a wing fabricating table. The firm's Cleveland foundries have cast two mold back-up tire sections said to weigh 8 tons and measure 8 ft. 10 in. in outside diameter for Goodyear Tire and Rubber Company. I. W. Wilson has been elected Chairman of the Board, and Frank L. Magee named President of Alcoa.

• **American Airlines, Inc.,** has announced the election of Walter G. Conrad as Vice-President and General Manager, American Airlines de Mexico, S.A., and G. Marion Sadler, Vice-President, Customer Relations.

• **American Steel & Wire Division, United States Steel Corporation** has announced the following promotions: Maxwell D. Millard to Assistant Vice-President, Sales, Howard B. Maguire to General Manager of Sales, and Norman M. Sted to Central Area Manager of Sales.

(*Continued on page 64*)



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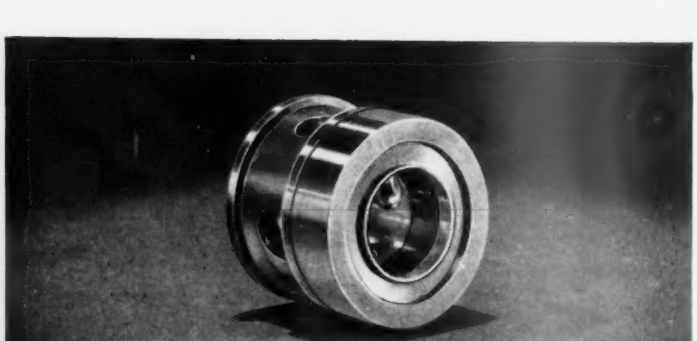
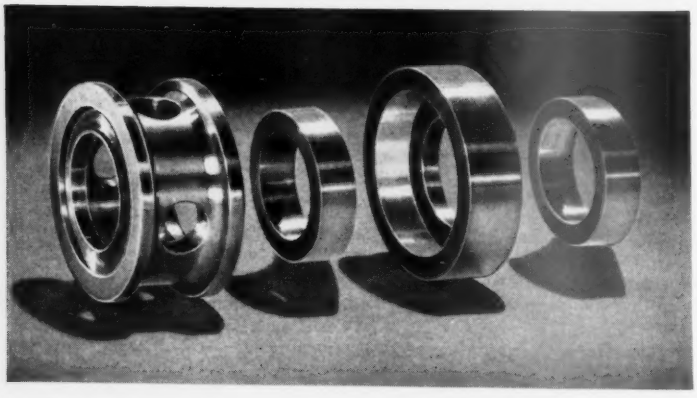


MULTIPLE RING TYPE Floating Ring Seal (assembled)



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Engineering and Scientific Briefs from Correspondents Around the Globe

Pressure Wave Collapse Scavenges Engine Cylinders

◆ A Swiss-patented design for an exhaust-gas-turbine supercharger involves the scavenging of the exhaust gases and the supercharging of the intake air of multicylinder, internal-combustion engines. The design, patented some time ago by Alfred Buchi, is of interest since the more efficient the scavenging process, the greater the charge of fuel and air taken into the cylinder for the subsequent cycle.

Buchi's patent specifies that the exhaust gases of the engine be ducted to the exhaust-gas-turbine supercharger. A pulsating pressure wave is created in front of the exhaust-gas turbine at the beginning of the exhaust period of each cycle. The sudden collapse of this pressure wave creates a suction effect upon the higher-pressure exhaust gases within the cylinder, and the cylinder is thereby scavenged. The exhaust gases are then ducted to the exhaust-gas turbine, which drives the compressor and produces the supercharging effect.

It is reported that the patent describes the device for carrying out this process, but descriptive details are not available.

Ceramic Rotor Blades Made by West German Firm

◆ Since before World War II, a West German firm has been doing research work on ceramic materials for turbine blading.

In a patent filed a few years ago in London, the specification described the dimension finishing of ceramic blades by machining a sprayed-on metallic coating, applied after the root section is fired. Since this technique was found to have certain disadvantages, the firm continued to work on the problem and filed for a new patent in mid-1955, which outlined a new processing technique in a new application. This specification suggests that the blade root be coated with a foamy ceramic which may be applied before the blade is fired. This protective layer on the seating surfaces absorbs any sudden, dangerous stresses on the blade and wears into a suitable area of support. The porous layer also impedes the flow of heat to the rotor disc.

According to the manufacturer, Maschinenfabrik Augsburg-Nuenberg, the blades are intended for use in stationary gas turbines.

Metal Deformation Studied by Two Soviet Researchers

◆ Exploring the failure of metals at temperatures to be expected in supersonic flight, two Russian scientists conclude that failure is not immediate—that the development of cracks leading to failure is progressive and time consuming. The researchers, Yakov B. Fridman and T. K. Zilova, also found in their series of tests that nonuniform, local deformation is absent until there are visible cracks, and both local and general deformation occur as these cracks propagate. They believe that examinations of fractured specimens can only lead to highly erroneous conclusions because local deformation occurs after failure has started. And they feel that, just as increasing importance has been placed on determining the start of plastic deformation, increasing significance should also be assigned to determining the start of failure.

These conclusions were presented in a paper titled "On the Process of Failure in Plastic Metals," which reported the results of tests using 40KhNMA in several conditions of heat treatment. The Russian researchers studied the deformation at three stages: (1) before there were visible cracks, (2) after the cracks became visible, and (3) after final failure.

In these tests, it was recognized that determining the precise grain boundary between elastic and plastic deformation is extremely difficult. (This value is usually approximated—for example, by a 0.02 per cent yield strength.) The equally difficult problem of determining the start of failure was approached by means of torsion and bending tests with specimen on which a grid was drawn. The tests were interrupted from time to time, and the surfaces of the specimen were inspected at about 27 magnifications.

In the United States, emphasis has been on the "first appearance of cracks" in fatigue testing, where various crack-detection methods are used—for example, magnetic tests. The idea of combining crack detection with the use of a grid to study nonuniform deformation is new.

This Russian research was done several years ago, both of the researchers having been active in the Soviet science world for a number of years.

French Propose Study of Scatter Propagation

◆ In recent years, a French firm has made a special project of the study and exploitation of tropospheric scatter phenomena for point-to-point communications. The company is responsible for the idea of a carcinotron transmitter, radiating 200 watts in the 4,000-mc. region, which, when used with a sensitive, wide-band receiver and two 28-ft. parabolic antennas, establishes a 200-mile propagation path. By sweeping the carcinotron across several tens of megacycles, the transmission-band characteristics can reportedly be studied dynamically and in detail. Current status of the project is not known, but, if French expectations have materialized, it should be paying off dividends by this time

Vietnam Expanding Meteorology Facilities

◆ The Directorate of Meteorology of Vietnam has announced that it plans to establish a Meteorology and Geophysics Center at Tan Son Hoa (near Saigon) during 1957–1958. This new installation will include a radio-sounding station, a station to study earth physics, a technical training course, a meteorologic observation section, and a section for testing and repairing technical apparatus. This center will also include a geophysical observatory and will be fitted with up-to-date equipment for magnetic, seismic, and actinometric studies.

In addition, it is planned to re-establish seven meteorologic stations—one each at Kontum, Hon Khoai, Bong Son, Chau Doc, Mui Nay, Mui Dinh, and Tien Sa—and to commission five vessels for meteorologic research and weather reporting. Last year, 26 new stations were established for recording rainfall, and weather stations were built and equipped at Phan Thiet, Quang Ngai, Phu Quoc, and Ca Mau.

EDITORIAL

By the addition of a few simple lines, the Institute's traditional "trade-mark" has been given new meaning—many new meanings. Some people see in it a system of mathematical coordinates or a set of conventional centerlines. Others see a missile or a rocket (from the south end, going north). Still others have said, "Ah, Sputnik!" Whatever the individual reaction, intent is to indicate that our interests extend into areas far beyond the confines of classical aerodynamics, as pointed up in the accompanying Editorial.

Zero to Infinity

No aeronautical events (including Kitty Hawk and Lindbergh's Atlantic crossing) have had such impact on human imagination as the recent Russian space flights. To the "man in the street" of America, they seem less the evidence of great scientific achievement than a threat of vague new dangers. After recovering from the momentary dismay of having been outsmarted at our own game by the Other Team, however, we believe that these things will, in the long run, prove more useful than damaging to us. (Already, Research and Development funds, cut heavily by the former Secretary of Defense, have been restored.)

We do not intend to take part here in the controversy of who is to blame for not getting ours up first. This falls into political rather than scientific areas. We leave that to our more vociferous brethren. We have no need to peddle our papers by stirring up already muddied waters. Least of all do we discount in any degree the prodigious technical and scientific effort behind the Russian rocket programs. The implications are clear and are profoundly disturbing. We know the requirements. We are well aware that things do not come about by accident. They cannot be created by politicians simply for "front" or propaganda purposes. As one rocket enthusiast said in a technical article a few days before Sputnik I appeared: "Putting a satellite in orbit is a ticklish proposition." This may be so, but the fact remains, it has now been done—and more than once!

If there were any lingering doubts in anyone's mind as to the technical capabilities of the U.S.S.R., such can no longer exist. There can be no question at all that the Russian program is directed by some of the best scientific minds in the world. These men are backed up by a large body of thoroughly competent mathematicians, research workers, and engineers, and their work is implemented by first-rate computing, research, testing, and manufacturing equipment. Behind all this is a long-range educational program reaching far down to the elementary schools designed to develop maximum interest and outstanding talent in scientific and engineering fields. There is an excellent account of the importance of science and engineering in the Soviet educational system in the October 18 issue of *U.S. News and World Report*.

From the technical and scientific viewpoint, the main consideration under the circumstances in which we presently find ourselves is to avoid any panic-induced deviation from our own long-range programs in support of our basic national interests. It would be unfortunate indeed if pressure from politicos and PRO's to produce immediate answers would cause us to make premature attempts to regain our position in the eyes of the world by firing off something that was not ready to go. **We can't afford to dawdle, but, at the moment, we have much more to lose from spectacular failures than we have to gain by spectacular successes. We can't afford a "Dud-nik"!**

We know that our technical and scientific foundations are sound. It is doubtful that there exists anywhere in the world any body of the competence and experience represented in the United States research community and in the U.S. aircraft and missile industry. They have been working together for a long time. We also are particularly proud to have played an active role. We have been in a favorable spot to sense and to anticipate trends in developments. Within the limits imposed by national security, we have made technical material in the most advanced areas available to our members. **For 25 years, your Institute has been the forum in which the scientific ideas behind our missile and satellite programs have been discussed and evaluated. The theories that have been developed in IAS meetings in the past decade have provided the solid foundation on which present-day missile and spacecraft flight concepts are based.**

The JOURNAL OF THE AERONAUTICAL SCIENCES has often been accused of being too "long-haired" for the average engineer. But we are dealing with very complicated matters which cannot be reduced to simple terms. If you look back through the issues of the past 10 years, you will find that the people who are doing outstanding work today in missiles, rockets, and space vehicles have published their findings and their theories (and are still doing so) in the JOURNAL. For example, the technical editor of a new publication specializing in space flight problems pointed out in an article in a recent issue that one of his earliest papers on the subject was published in the Institute's JOURNAL for August, 1947 ("The Problems of Escape From the Earth by Rocket" by Malina and Summerfield). Such examples could be multiplied many times.

In order to determine whether we have been anticipating today's requirements in our meetings' programs, we have made a detailed analysis of some 342 technical papers presented in the nonspecialized Regional Meetings of the Institute during the past 18 months. We have classified each with respect to its application to the five categories of aerial vehicles in which we are interested—e.g., Aircraft, Missiles, Rockets, Satellites, and Spacecraft. Of the lot, 154 papers (approximately 45 per cent of the total) had direct application in the fields of Missiles, Rockets, Satellites, and Spacecraft. Many of them dealt with the specialized electronic devices and other accessories needed for their guidance and control. A similar review of nonspecialized National Meetings yields results of the same order. About 50 per cent of the papers presented have direct bearing on Missiles, Rockets, Satellites, and Spacecraft and their ancillary equipment. In addition, the National Flight Propulsion Meetings, which have been held each March for the past 10 years in Cleveland (with NACA cooperation), have latterly tended to center attention almost exclusively on missile and rocket problems. Out of these classified (SECRET) meetings have come some of the most far-reaching and important papers produced on these topics. They have been distributed to industry by ASTIA on a need-to-know basis. **Altogether, something of the order of 350 first-rate scientific and technical papers on missile and rocket matters have been presented under IAS auspices in the past year and a half.**

More and more frequently, particularly in the missile and rocket fields, the Institute conducts classified conferences closed to general attendance at both national and regional levels. These conferences range from specialist meetings to national meetings. For such meetings, the attendees must meet strict security requirements—including certification of personal clearance and need-to-know—by their own organizations and the cognizant military authority. Special arrangements always made under official supervision at the meeting place guarantee security of the discussion, both in physical arrangements and proper identification of participants.

REVIEW readers also know that an increasing percentage of the more engineering-type paper is devoted to such subjects. Unfortunately, many worth-while papers on specific applications are still classified and cannot be published. These are carefully followed up for treatment as soon as they can be released by proper authority. We see no virtue in so-called "scoops" which teeter dangerously over the line of national security.

Indexing, cataloging, and abstracting (by the REVIEW and Library staff) of thousands of articles from the scientific and engineering publications of the world is an important monthly contribution. Partial support in this effort is provided by ARDC-USAF. The subject matter of these Reviews covers every area of science and engineering. **Current interest in Missiles, Rockets, Satellites, and Spacecraft is reflected in the increasing number of items appearing in these categories in each issue.**

It has always been IAS policy in arranging its programs and in editing its publications to keep ahead of the requirements of its members (see the Editorial "The Job Before Us," July, 1956, REVIEW). We have been fully aware that emphasis has been shifting in the past few years from subsonic to supersonic, from air-breather to self-contained engine, from air-borne to space vehicle. We have never considered that the interest of our members stopped where the atmosphere thinned out to the point where wing-supported flight became impossible. We see no basis for the argument that there is any essential difference between Aeronautics and Astronautics. The latter is only a part of the larger whole. **Aeronautical Science embraces the flight of any vehicle that leaves the surface of the earth and goes anywhere, by whatever means.** No one could argue that the interests and researches of the National Advisory Committee for *Aeronautics* or the Navy's Bureau of *Aeronautics* should be limited to altitudes below 100,000 ft. And so, as the Institute of the *Aeronautical* Sciences, we will continue to serve (in a strictly nontheological sense) the interests of our members at all altitudes from Zero to Infinity.

S.P.J.

An Outline of *Things to Come*

Traffic in the sky is getting faster and hotter—with no limits in sight. But the rate of further progress is not locked merely to the ability of materials to withstand speed and heat. A significant factor is the time lapse until they become a production line product. More than a sheet of "dream" metal, rolled in the laboratory, is necessary before arrival of the Tomorrow with which this report is concerned.

TOMORROW'S air weapons systems cannot be built with today's manufacturing technology. We have designs right now that cannot be produced and materials that cannot be utilized effectively. We must develop manufacturing processes and equipment to turn these new materials and advanced designs into production parts.

With ever-increasing flight speeds, aircraft and missiles structural components encounter the ever-increasing temperatures of the "thermal thicket." Even today the external surfaces of our new aircraft must withstand temperatures of 600 to 800°F. Tomorrow these temperatures will be even higher. Within the aircraft body there are many sources of even more intense heat, such as the engine, which create temperatures higher than those in your backyard bonfire. New heat-resistant materials must be used.

We are not eliminating our old friend aluminum from future aircraft—we are adding titanium, stainless steel, beryllium, tantalum, tungsten, and other high-temperature-resistant materials to the design engineer's family. Merely possessing a new material does not help us produce superior performance aircraft. There is a big step from being the laboratory curiosity, such as aluminum once was, to everyday use by the aircraft fabricator. Somehow we must bridge this gap between the laboratory curiosity or breadboard model and the production line product.

Manufacturing methods bridge this gap. The Air Force responsibility for developing production line manufacturing methods and equipment lies with the Manufacturing Methods Branch (MCPBM), Industrial Resources Division, Air Materiel Command, Wright-Patterson Air Force Base, Ohio.

The authors are, respectively, Chief and Technical Assistant, Manufacturing Methods Branch, Industrial Resources Division, Directorate of Procurement and Production.

Manufacturing Methods Branch

The Manufacturing Methods Branch programs are aimed primarily toward anticipated manufacturing problems of 1 to 3 or more years in the future. We would much rather prevent fires than exhaust ourselves in putting them out. Although we often must attack current manufacturing bottlenecks, we feel amiss at not having anticipated such bottlenecks sooner and thus prevented the fire. We try to anticipate the requirements of the weapons systems designers even before such requirements have been formulated in their own minds. This business of "out-dreaming" the designer requires considerable ingenuity and courage if processing and production requirements are to be met.

In addition to providing direct support for many programs, the Manufacturing Methods Branch strives to be a focus for manufacturing methods knowledge. To be a focus of knowledge is not to be a repository of knowledge but rather a directory which helps the production engineer locate the information desired.

In fulfilling its mission, the Manufacturing Methods Branch utilizes some 30 technical engineers with many years of industrial and governmental experience in various specific areas of responsibility. These engineers consider about 300 ideas each year from which some 30–40 result in new contracts. We feel that our contractors become temporary members of our team such that we have some 200–300 engineers lending their full efforts to our manufacturing methods development efforts. For functional convenience the Branch is divided into four operating sections: Basic

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Industry, Machine Tools, Electronics, and Methods Engineering.

Basic Industry Section

The Basic Industry Section is concerned primarily with the functions of casting, rolling, forging, and extruding metallic materials.

Remember, every piece of metal in use today was born a casting; even the lowly pig iron is the ancestor of the highest powered steel. Basically, the casting process offers the best chance to produce a part in the rough which will be the closest possible approximation of the finished piece. Many parts may be held to such close tolerances in casting that the only machining required will consist of drilling a few bolt holes and, possibly, facing off mating surfaces. Such castings reduce the amount of machining, reduce the waste of scrap metal, and may eliminate many hand operations in forming finished parts. For example, a landing-gear door has been made as a one-piece magnesium casting, replacing 55 aluminum stampings held together with over 1,600 rivets.

Although much remains to be done to improve the state-of-the-art of casting, we already have steel casting alloys which possess a strength of 200,000 psi and are working toward the 300,000 psi range. We are endeavoring to improve the casting of titanium so as to produce consistently homogeneous ingots of the newer high-strength titanium alloys free of contamination. We also are studying the possibility of casting beryllium which, at the present time, can be prepared only by the powder metallurgy method.

How do we ensure that our cast metal is free from undesirable elements and that it in turn does not contaminate the atmosphere and its surroundings? We will require advanced equipment and techniques such as the vacuum furnace, the consumable electrode vacuum melting furnace, the electron beam furnace, and others yet to be dreamed of.

As the aircraft of the future fly faster and faster, so must the materials going into their structure be tougher and more heat resistant than the commonly used aluminum of today. The use of these stronger and more heat-resistant materials, such as the stainless steels, imposes more severe weight penalties on the designer and fabricator. For example, the designer specifies the minimum thickness steel sheet which will provide the structural integrity desired. However, in actual fabrication, the use of steel sheet with the present commercial thickness tolerance on a wing surface of 4,800 sq.ft. imposes almost 2,000 lbs. of excess weight. How much more range would the aircraft have if this excess steel weight were available as fuel! Programs are either under way or being studied to develop methods and processes to produce homogeneous titanium and stainless steel sheets to thickness tolerances of 2.5 per cent or less. Beryllium, still only a dream metal for aircraft use, has been rolled into sheet form in the laboratory. Now we must develop methods for consistently and safely rolling high-quality beryllium sheet in large quantities.

As with casting and rolling, we find new problems in forging and extruding new titanium, stainless steel, and beryllium alloys. Unfortunately, these materials do not have the same forging and extrusion characteristics as the well-known aluminum: processing temperatures are much higher, scale formation is severe, detrimental gaseous impurities are absorbed from the atmosphere, and serious variations occur between the transverse and longitudinal properties of fabricated parts.

Possible solutions to the varying problems lie in the use of new die materials, new die designs, new forging and extruding lubricants, protective coatings for the hot billets, controlled atmospheres, and new forging and extruding techniques such as the use of explosives to create extremely high deformation rates. Perhaps we will find our entire casting and forming operation performed in a large vacuum chamber, such as a large sphere of the type now used to contain nuclear reactors, complete with automatic controls.

Complete success in our Basic Industry projects would eliminate many machining operations. However, we do not expect complete success, and, even if such were attained, there are still many machining operations required. The development of techniques and equipment to perform these required machining operations is the function of the Machine Tool Section of this Branch.

Machine Tool Section

Aluminum is one of the easiest metals to machine. Working with this old stand-by is like working with modeling clay, whereas machining the newer high-strength heat-resistant materials is like substituting hardened cement for the soft clay. Current tech-

TITANIUM FABRICATION SUMMARY

FOR J-65 ENGINES

	EXTRUDED SHAPES	SHEAR SPINNING	RADIAL EXTRUSION	TOTAL
NUMBER OF PARTS	15	15	23	53
ROUGH WEIGHT SAVINGS	174 lbs	127 lbs	744	1045 lbs
COST SAVINGS	$ 3,557	$ 2,811	$15,420	$ 21,788

FIG. 1.

nology permits cutting speeds on these newer materials to be less than 1 per cent as fast as cutting speeds for aluminum. Machining the increased quantities of high-strength heat-resistant alloys by current conventional methods is estimated to require at least four to ten times the machines, floor space, and manhours now required for the aluminum alloys. It is unlikely that we can afford the luxury of using conventional low-speed cutting techniques. We must explore the possibility expressed by the Salomon theory that there exists a speed range, much higher than the speed range used in conventional machining operations, where there is increased tool life and lower cutting temperatures rather than a decrease in tool life and higher cutting temperatures. What these cutting speeds will be, we do not know. It may be necessary to use entirely new techniques to achieve cutting speeds fantastically far beyond those used even in machining aluminum. All we can say is that we must push ahead.

Of course, it would be desirable to eliminate cutting operations entirely, especially when costly new alloys are involved. Many possibilities exist for the use of roll forming techniques by which metal is caused to flow into the proper shapes rather than be removed. When combined with precision extrusions and/or precision forgings, the greatest savings in material waste will be attained. A recently completed contract with Curtiss-Wright has demonstrated the significant savings attainable by combining precision extrusion with a modification of roll forming instead of using conventional forging and machining in the production of parts for the J-65 turbojet engine (Fig. 1).

In addition to the conventional cutting-type machining operations, "chipless machining" methods have been developed for removing stock from a workpiece without producing a chip. Among the processes included in "chipless machining" are chemical milling, electrogrinding, electrospark machining, electrolytic milling, and ultrasonic machining—each of which uses one or more mechanical, chemical, or electrical phenomenon to effect the removal of metal from the workpiece.

Chemical milling uses chemical action to remove metal from deliberately exposed surfaces. Although the initial and most predominate application of this process has been on aluminum, present development work by private industry is extending the application of chemical milling to ferrous and titanium base alloys. Chemical milling is an example wherein industry has developed a technique without direct Government funding or monitorship. In this case the Manufacturing Methods Branch maintains surveillance so as to ensure that the present pace of development and dissemination of information is satisfactory.

The electrolytic process in its most basic sense is a refinement of chemical milling. In this process an electrical current is used to aid the chemical etchant in removing the metal from the exposed surface.

It is in the area of electrospark machining that the future of machining metals looks the most promising. There appears to be no limit to the characteristics of the process—the harder the metal, the better the performance of the electrospark machining process. In this method there is little or no relative motion between the workpiece and the "cutting" tool. The so-called cutting tool is actually an electrode which serves to generate the desired workpiece contour by pulsating discharges of electrical energy which progressively disintegrate the surface of the workpiece.

Regardless of the application, wherever relative motion between the workpiece and the working tool is required, there is a possibility of using numerical controlled machine tools. Numerical control is the guiding of the working tool over the workpiece, without human intervention, by a series of instructions in the form of electronic impulses which were previously recorded in numerical code on film, magnetic tape, punched cards, or punched tape.

Originally conceived and sponsored by industry, further development was sponsored and monitored by the Manufacturing Methods Branch starting early in 1949. By the end of 1955, many machine tool builders were showing a strong competitive attitude regarding machine tools augmented with numerical control. Present development programs sponsored by the Air Force are primarily confined to the future development of data programing systems to augment the original project work and to apply the techniques to additional areas, such as die sinking machines. Among the many benefits obtained from numerically controlled equipment are decreased setup time, increased accuracy of dimensions, convenient storage of skills, rapid interchangeability, elimination of human error, increased machine utilization, and the possibility of less material scrap. The advent and production availability of numerically controlled equipment has been of such importance that one of the major aircraft producers expressed his feelings in this fashion: "Within the life span of our company, there has been no other comparable radical manufacturing improvement."

Electronics Section

With 50 per cent of the Air Force procurement dollar buying electronic equipment and components, the Electronics Section of the Branch has a great responsi-

bility. The Electronics Section has the common objectives of increased producibility for any individual item, improved manufacturing techniques including miniaturization, and improved process equipment. However, in no other section is the requirement for reliability quite so strong. How reliable must any particular electronic component be? From the laws of probability we know that, if there are ten components joined together, each of which is 90 per cent reliable, the system using these ten components is only 35 per cent reliable. By the time we place several thousand components in a missile penetrating to the outer limits of the earth's atmosphere and encountering hitherto unknown environmental conditions, reliability of each component must go far beyond the dreams of yesterday.

Satisfying the requirement for reliability of the finished electronic system is being attacked two ways: by producing more reliable individual components and by developing techniques for predetermining the reliability of any single component or system. Missiles streaking at high supersonic speeds through space are subject to severe shock, vibration, and temperature conditions hitherto unencountered. Ordinary glass or metal receiving tubes, no matter how ruggedly built, still fall short of the designer's requirements. Ceramic electron tubes have been developed which perform satisfactorily at temperatures of 500°C. (932°F.) and withstand shockloads of 1,000*g*. These tubes are so reliable that they can be permanently wired into the electronic system circuit, eliminating the necessity for tube sockets with their attendant unreliability.

These ceramic receiving tubes, in addition to being highly reliable, are designed for automatic mechanized assembly with a minimum of hand labor. This design utilizes the principle of stacking self-jigging ceramic units into small subassemblies. Similar techniques are being pursued in the direction of cheaper and more reliable electronic relays, capacitors, resistors, and other components.

Predetermining the reliability of components becomes a nightmare for the fabricator of a missile which must travel 5,000 miles to a target without failure. Present testing techniques depend upon statistical probability determined from destructive testing. Perhaps the statistics show that only one part in one million will be unreliable, but this does not solve the fabricator's nightmare of determining which is that one part that is unreliable. Therefore, we are trying to develop nondestructive tests which will indicate in advance the one unreliable part in a million so that the fabricator will know for certain that he has installed good parts throughout his vehicle.

Methods Engineering Section

Last is the Methods Engineering Section which will catch almost any problem thrown to them. This section covers such varied projects as improving the reliability of reinforced plastic laminates through the study of processing and other variables; the development of extremely high temperature aircraft glazing materials; the production of exotic high energy fuels; improving methods for making high-temperature-resistant sandwich materials; sheet metal forming; and establishing design criteria for materials including formability, weldability, machinability, as well as the standard strength properties.

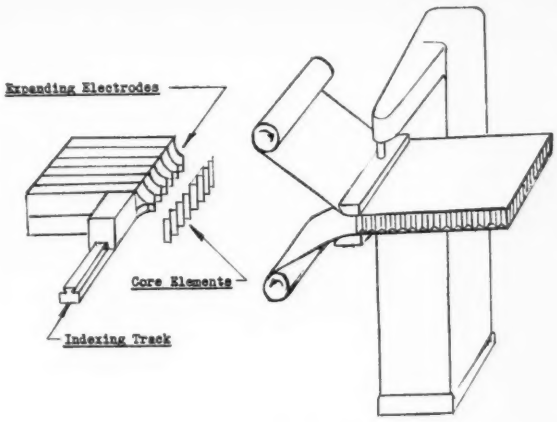

FIG. 2. Automation assembly of honeycomb core sandwich.

Inexpensive, reliable, high-strength, heat-resistant sandwich materials might well be a serious rival in many areas for castings, forgings, extrusions, and other similarly fabricated parts. This is especially true in the temperature ranges wherein aluminum and magnesium are becoming marginal in useful strength. Of course, at some temperatures it will be necessary to convert from these extreme lightweight metals to the more dense titanium or steel. The use of titanium or steel as sandwich provides the strength required without the penalty of excess weight such that steel sandwich may well be used competitively at far lower temperatures than otherwise would be the case. However, sandwich will not be fully utilized until its price is reduced from several hundred dollars per square foot to only a few dollars a square foot. Several ideas are being investigated (one is depicted in Fig. 2) for the automatic production of sandwich material with high strength and heat resistance yet at a very low cost. Such a machine has operated on a semilaboratory scale but has yet to be placed into production scale operation.

In addition to developing new or improved techniques and equipment, the Branch often has provided a domestic source of critical military items which heretofore have been obtainable only from overseas producers. A prime example occurred during World War II when it was quite a cloak and dagger exercise to smuggle miniature jewel bearings out of Switzerland. A successful project to mechanize production of synthetic sapphire jewel bearings has not only provided this country with a domestic source but has also created

(*Continued on page 35*)

Testing Aircraft NUCLEAR Power Plants

A. R. Crocker, General Electric Company

A discussion of the techniques, procedures, and restrictions which permit the accomplishment of a testing program in a complete and safe manner.

It was announced a few months ago by the Atomic Energy Commission that some tests of aircraft nuclear power plants were under way and, more recently, that a turbojet engine was powered exclusively by heat from an experimental reactor.[1]

These tests were conducted at the Initial Engine Test Facility which is located at the U.S. Atomic Energy Commission's National Reactor Testing Station 55 miles west of Idaho Falls. This facility is one of several which are operated by the Idaho Test Station, Section of the General Electric Company's Nuclear Propulsion Department, under contract to the USAEC and USAF. The headquarters for the Department is in Evendale, Ohio, where the design work and the component development takes place.

The development of an aircraft nuclear power plant is similar to that of chemical power plants with the addition that the work must be performed within the framework of restrictions imposed by the nuclear reaction. This paper should indicate some of the differences involved in testing the power plants.

The facilities that are in use are first described, then the preparation for test is mentioned, and finally the instrumentation and the operation of aircraft nuclear power plants are discussed. Information on the characteristics or performance of the power plants cannot be given.

The Idaho Test Station, like Gaul, is divided into three parts—a service area which includes engineering and administration, a shop area, and a test area.

In the service area there is an engineering and administration building which houses engineering, accounting, security, employee relations, etc. A maintenance building houses the crafts. Another building contains the dispensary, fire department, ambulance, garage, and steam plant. In order to support a test function 1,800 miles from home base, it is necessary to duplicate practically all of the components found in a normal plant.

The shop area is separated from the service area by a natural ridge. The main feature of this area is the assembly building which provides facilities for assembling power plants for test and for disassembly after test, either by direct contact or by remote means. Fig. 1 shows the building layout. The machine shop and engine overhaul space is located in the lower bay. The first assembly of a power plant is done in the next bay, called the cold shop, so named because it is

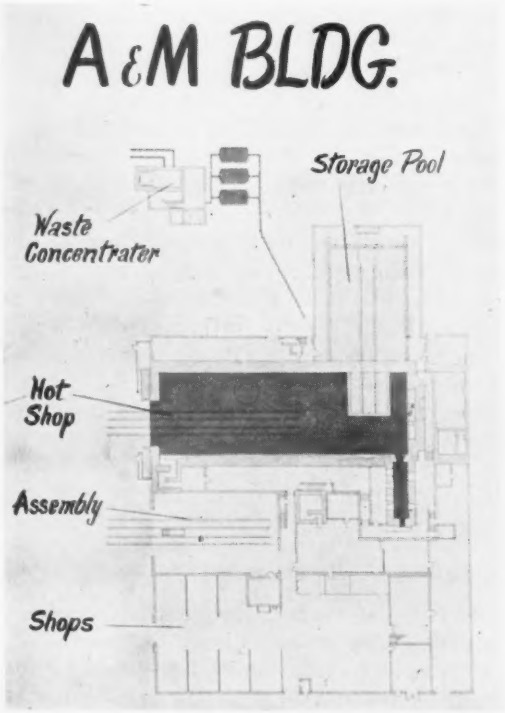

Fig. 1.

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radioactively cold. This is in contrast to the hot shop which is a room 50 ft. wide, 160 ft. long, and 60 ft. high and surrounded by concrete walls 7 ft. thick. Within this latter area, power plants can be assembled and disassembled by remotely operated manipulators, special jigs, and tools. At one end of the hot shop is a storage pool for holding radioactive parts for future use.

On the opposite side of the hot shop, and communicating with it via a remotely operated plug door, is a radioactive materials laboratory. This is a so-called hot cell where highly radioactive components can be viewed through windows and periscopes, dissected by metallurgical and machine tools, and examined in a variety of ways, all by remotely operated equipment. An interior view is shown in Fig. 2. A General Mills manipulator is shown mounted on a crane bridge. It will lift 40 to 750 lbs. depending on the position of the hand. Normally, the room is filled with tables on which are placed the tools and apparatus for doing this work. Some of the remotely operated machine tools in use are a lathe, milling machine, and grinder. Other equipment includes scissors, specimen mounting presses, canning machine, and balance accurate to a milligram. As can be easily imagined, this is a gadgeteer's paradise. The specialized equipment and techniques devised for this phase of the business is a subject in itself. After completion of examination, radioactive components are literally canned up, placed in lead pigs as required from a radiological safety standpoint, for transportation to other locations.

Fig. 3 is a view of the interior of the hot shop showing

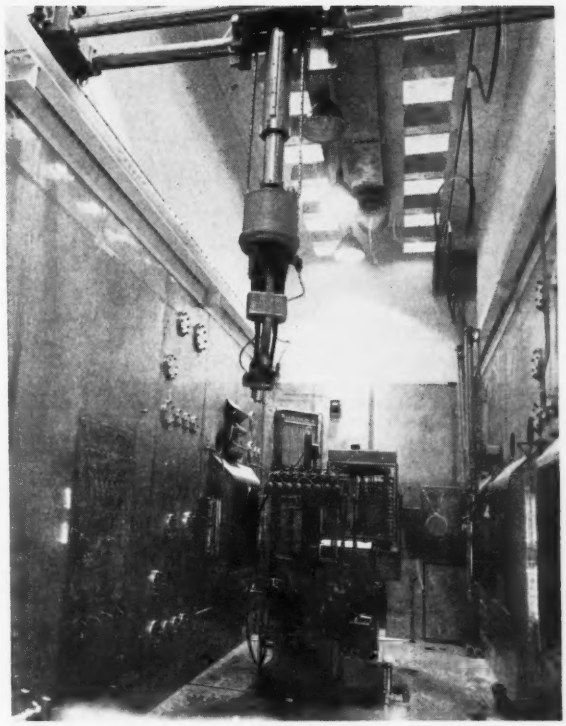

FIG. 2.

the overhead crane, turntables, and utility pedestals. The latter contain outlets for electricity of various voltages, water, compressed air, and acetylene. Fig. 4 is a picture which was taken through a hot shop shielding window in a control gallery and shows wall-mounted

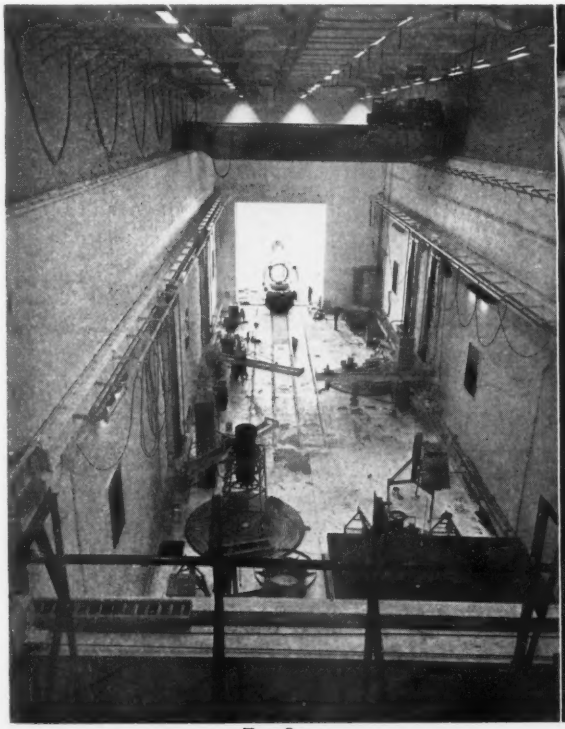

FIG. 3.

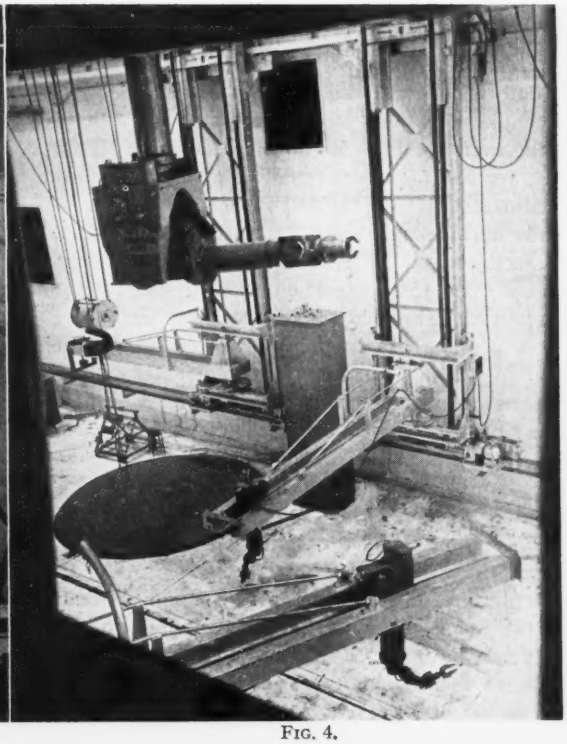

FIG. 4.

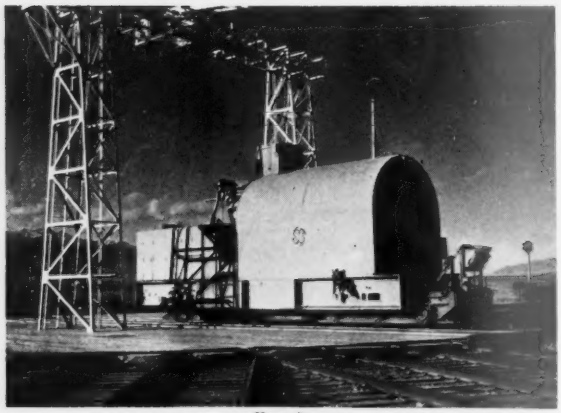

FIG. 5.

manipulators which can reach into any area in the hot shop and the overhead manipulator. The latter will lift 500 to 3,000 lbs. depending on the arm position. All manipulators have a variety of hands which permit many different operations.

The power plant is assembled on a dolly which is similar to two flatcars fastened alongside each other, thus requiring a four-rail track. The power plant is pushed from one place to another by a shielded locomotive. This is shown in Fig. 5. Transfer from one set of tracks to another is accomplished by this remotely operated turntable.

One set of tracks leads to the Initial Engine Test Facility located 6,000 ft. to the north. An exterior view is shown in Fig. 6. The main building is below grade level, thus utilizing the most inexpensive shielding material—dirt. A general floor plan is shown in Fig. 7. The locomotive mentioned previously pushes the power plant to the IET and into the test building. The dolly is anchored in place by two standard railway-car couplers. A plug 19 ft. long and 1 ft. wide protruding from the dolly fits into a recess in the facility. All power leads, process piping, and instrumentation and control leads from the dolly terminate in disconnect fittings on this plug. Within the IET coupling station these connections are mated with the facility lines. This coupling area is reached by a tunnel from the main part of the building.

It is possible to observe the power plant during operation through the use of two periscopes whose eyepieces are inside the control room. They terminate at the rear of the power plant, one on each side. One is 60 ft. long, and the other, which is 90 ft. long, is believed to be the longest periscope in the world. A bank of flood lights on each side of the test cell provides light for viewing the power plant.

When the reactor is at low power, personnel with health physics and security guard escort may enter and leave the area. When the reactor is at high power, the facility may be approached by personnel in the shielded locomotive who then descend through a hatch between the center tracks and enter a tunnel which communicates with the data room.

The opposite end of the building is devoted to supporting equipment. A diesel generator floating on the line supplies emergency power in case of utility power failure. A compressor supplies air for turbojet starting and to other pneumatically operated equipment. A series of m-g sets supply 400 cycle and 28 volts of d.c. power for aircraft systems. All air coming into the control and equipment room is passed through two filters and a washer. Space pressure and temperature are controlled throughout the building. Within the control room and data room humidity is also controlled.

Preparation for test is not unlike that of testing other power plants with due regard for the associated nuclear problems. Several check lists are filled out. There is one for the facility equipment which includes 16 items. Some examples from this list are as follows:

The emergency diesel generator must be operating properly and the quantity of fuel remaining noted. The periscopes are operated, the radio transmitter and receiver tested, the sump pumps throughout the building checked, all intercom stations are operated, and the emergency lighting system tried out.

Another check list is for the auxiliary mechanical apparatus on the power-plant dolly which has 31 items. The reactor-engine instrumentation and controls operation are checked off on another sheet having 23 items. Twenty safety circuit points are set and checked before operation. Some of these will be mentioned later. A weather check list is completed by health physics personnel.

The engineer-in-charge has a check list of his own. He inspects each of the completed check lists mentioned

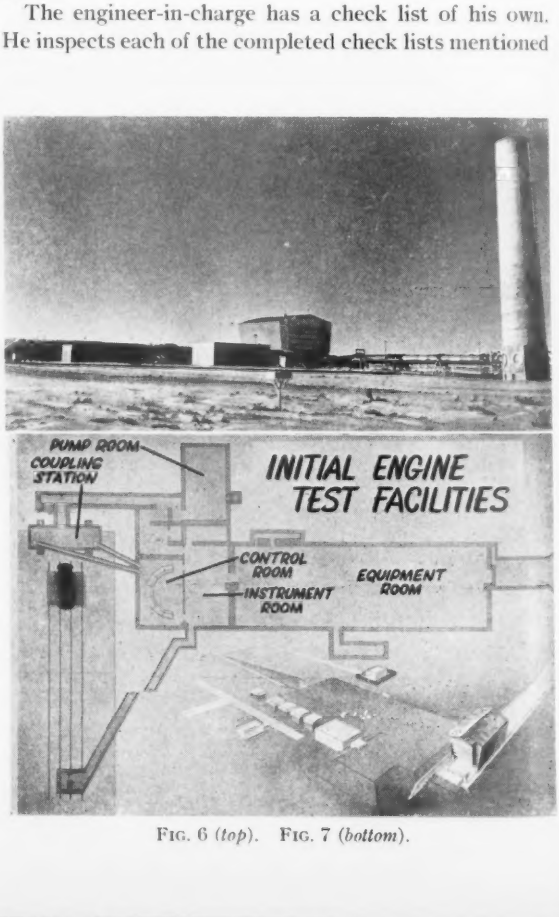

FIG. 6 (*top*). FIG. 7 (*bottom*).

above, notes them on his own sheet, visually inspects the power plant and coupling station, and compiles a list of all personnel in the area.

On notification from the engineer-in-charge the security guard locks the perimeter fence and enters the control and equipment building. Since an exchange badge system is used, the security guard has badges of all personnel within the area. He compares this with a list of personnel the engineer-in-charge has compiled. In this way all personnel are accounted for and duly noted on the check list.

Health physics personnel rope off all exits and remain available to make radiation surveys and prescribe exposure time limits and special clothing requirements whenever contact with radioactive components is required. A siren on the building roof is sounded to warn any personnel who might have come into the general area without being detected. The reactor "ON" lights at the exits are lit, as well as one in the engineering office area, and the power plant is ready to start up.

The power plant is operated from a console in the control room shown in Fig. 8. Since this is a facility for development testing of the power plants, there is obviously more instrumentation than that required for production or flight test. In general, the engine instrumentation is grouped on the panels at the left side of the console. The usual turbojet instrumentation is included. The reactor instrumentation is grouped on the right side. That and the keyboards will be mentioned later. Secondary panels behind the console contain amplifiers and power supplies although some temperatures are displayed there. All instrumentation sensing signals are transmitted electrically.

Prior to complete power-plant tests at this facility, the components undergo individual tests. Turbojet engines are tested with simulation of the pressure drop imposed by the type of heat exchanger that supplies the heat generated by the reactor. The reactor undergoes a critical experiment where at essentially zero power the variation of power distribution throughout the inside of the reactor is examined in detail by the activation of foils and wires. The control system, mechanical components, and other features are checked carefully before the assembly is brought to this facility.

In testing chemical engines, the characteristics of the device are determined by measuring such quantities as r.p.m., fuel flow, pressure, thrust, or torque. These are mechanical quantities whose effects can readily be seen, heard, or felt. Engineers have good mental pictures of them. To determine what is taking place within a nuclear reactor, it is necessary to resort to measuring more abstract quantities, but nonetheless, real. The fission process in a thermal reactor is caused by a collision of a neutron of thermal energy with a nucleus of a U-235 atom. The fissioning releases more neutrons. The continuation of this process makes the reaction self sustaining. Since neutrons are the star performers, their actions are monitored. During start-up there are relatively few neutrons causing fissions. The

FIG. 8.

energy pulses from a fission chamber located in the reactor are counted in units of pulses or counts per second, or more exactly, the logarithm of the count rate. This log count rate is indicated and recorded on a strip chart.

This fission chamber is a highly sensitive thermal neutron sensing device which contains a plating of U-235. Fissions taking place within the chamber create ionization in bursts. The charge collecting on the center electrode feeds a pulse to an amplifier.

The reactor is started by withdrawing a poison which is a material that is a strong absorber of neutrons. When the neutron chain reaction is self sustaining it is said to be critical. The reactor power in this region is of the order of a few watts. As more poison is removed from the reactor and the fission rate increases, the neutron pulses in the fission chamber occur so rapidly they cannot be counted as discrete pulses and so a current is measured instead. This is accomplished in an ion chamber which is close to the reactor core.

This current is related to the neutron flux. The flux is defined as the number of neutrons passing across a square centimeter per second. As the reactor goes to full power, the flux will increase by several decades. In order to keep a reasonable scale, the logarithm of the flux is taken. Also the derivative of the log flux is taken electrically. This gives a quantity called the period in units of seconds which is the length of time required for the reactor to change its flux by a factor of e. It is thus analogous to the time constant of a physical system. The period may be positive or negative depending on whether the reactor is increasing or decreasing power. If the power is constant, the period is infinite. This is an important measurement during power change. Safety circuits are another feature of nuclear reactors which is different from that normally encountered in testing chemical engines. If a master rod breaks, or blades or buckets come loose, or a combustion chamber explodes, the debris is simply and mechanically removed. If there is a nuclear accident, the radioactive debris can result in a health hazard. To prevent the remote possibility of this occurrence, elaborate precautions are built into the reactor control circuit so that too fast a period, too high flux, loss of coolant flow, or other things will automatically set back the power or even "scram" the

FIG. 9 (*top*). FIG. 10 (*bottom*).

reactor. The term "scram" is used to mean the rapid insertion of a neutron poison into the reactor. This poison absorbs neutrons making them unavailable for carrying out the chain reaction and thus instantaneously shutting down the power plant. The control system must provide throttle control for changes in power, as well as long-term effects such as poison build-up in the reactor and fuel depletion. It must also be combined with the turbojet control system, such that engine speed and reactor temperatures are maintained within the desired limits.

At still higher reactor power, the flux is measured and indicated on a linear scale usually in terms of 0 to 100 per cent of the full power flux. This may be considered to be a power meter. The reactor power as indicated on this meter is the result of a calibration of the ion chamber and its associated circuitry. Although this determines the power at a particular spot in the reactor, it is corrected to indicate the overall nuclear power generation. A better value of power is obtained from a heat balance calculation based on direct measurement of the pertinent parameters. In considering the reactor as part of a power plant, it is, of course, necessary to measure coolant flow rate, pressure, and temperature distribution. These quantities are indicated on the power-plant console.

No data are written down by the power-plant operators. A running log is maintained by the engineer-in-charge, who, from time to time, before, during, and after a test, records pertinent information on a dictaphone. This is later transcribed as an official operating log.

There is another grouping of instrumentation important to power-plant operation which is shown in Fig. 9. It includes indication of the status of auxiliary apparatus on the power-plant dolly and on the facility. The barometric pressure, humidity, wind direction, velocity, and temperature gradient on a tower in the test area, as well as the radiation levels throughout the IET area both inside and outside of the building, are displayed here.

It is necessary to record the power-plant performance so that a comparison can be made with design predictions and a basis obtained for making improvements in the next design. The data recording system is shown in Fig. 10. Described briefly, analog temperature signals from thermocouples and pressure signals from electrical transducers are fed into seven 80-channel Brown recorders. Just below each recorder is a patch panel which allows flexibility in changing channels of information. A digitizer on each recorder slide wire balancing mechanism transmits the reading to an IBM tabulator. Simultaneously one channel from each recorder is tabulated. As the system scans each of the 80 points on each recorder, the tabulator prints the reading and punches a card. The scanning system is interlocked so that each recorder keeps in phase with the other recorders. A complete set of data of 560 points is thus recorded in approximately 3 min. The cards are fed into a programed IBM 650 computer which, within 5 min., will do a number of important calculations such as a heat balance on the system.

Practically all of the data are recorded on strip charts in the data room while being digitized andtab u-lated. However, there is some information at the present time, such as exact engine r.p.m. and barometer reading, that does not go through this process but is manually punched into a keyboard in the control room and directly tabulated. In cases where a strip chart recorder is located in the control room a retransmitting slide wire supplies the signal to the recorders in the data room.

As is typical of other power plants, the thermodynamic data get primary attention. Temperatures, pressures, and flow are recorded such that the heat produced by the reactor and the heat losses through the system can be computed. The heat-transfer coefficient of the heat-generating material is determined. The pressure drop of the working medium at various points through the system is measured. Turbojet engine performance is computed.

Nuclear data are also obtained. The excess reactivity is measured at intervals. This is of special interest when the effect of build-up and decay of xenon poisoning is determined.

The term reactivity should be defined. It is the number of neutrons existing at the end of one generation compared to the number existing at the beginning.

The difference between the two being the excess reactivity.

Some of the other typical nuclear measurements are the moderator temperature coefficient of reactivity and the effect of the control poison on the reactivity and thermodynamic characteristics of the reactor.

In the case of response tests of the control system records are made on galvanometer-type recording oscillographs. For this test, the scanning system is halted and the oscillograph is plugged into the data panels at outlets located below the patch panel.

Donald L. Francis, Supervisor of the Test Program & Analysis Unit, was largely responsible for the basic design of the data handling system which has worked very satisfactorily from the time it went into operation.

In summary, this paper has mentioned some of the factors involved in the testing of the aircraft nuclear power plants. Many of them are new to the aviation industry because they are peculiar to the characteristics of the nuclear heat source. But the application of suitable procedures and techniques permit the accomplishment of a testing program in a complete and safe manner.

REFERENCE

[1] *Major Activities in the Atomic Energy Program—July-December, 1956*, Government Printing Office.

* * *

An Outline of Things to Come *(Continued from page 29)*

a production capacity sufficient to export jewel bearings. Application of the ultrasonic cavitron process, developed by us, has enabled a single machine to produce 55,000 jewel bearing blanks in an 8-hour day compared to former production rate of only 300 to 400 blanks per day per person.

A project to help solve one of the biggest headaches of the Air Force has just been started. Deterioration of Air Force materiel in long-time storage throughout the world can create as much loss as extensive enemy operations. A laboratory device which anticipates corrosion of stored articles has been developed, and it is now our job to see that this device can be produced in the large quantities required by the packaging people. The device consists essentially of an extremely thin film of metal deposited on a nonconducting glass or plastic substrate. The thin film corrodes more rapidly than the material being protected in the package and thus anticipates possible deterioration sufficiently in advance for the package to be resecured before an engine or other costly item has been damaged.

CONCLUSION

We have shown a few examples of the type of work performed by the Manufacturing Methods Branch. A detailed description of all work performed under the auspices of this Branch is beyond the scope of this paper. We have not even attempted to describe all the possible new materials which must be fabricated and formed into future weapons systems. We can only hint at the problems that will be created by the severe environments encountered by high-speed aircraft and missiles in the supersonic and hypersonic ranges, at the materials developed to meet these problems, and at the methods of producing useful components from such materials. The challenge is great. We hope that readers will come to us with specific solutions to problems so that we may better fulfill our Air Force mission.

In general the function of the Manufacturing Methods Branch is to assure that better ways are found to manufacture the better things which are developed through research and development, thus bridging the gap between research and production.

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Specific criteria assumptions needed in performing drawing-check stress analyses, as well as those which should be known prior to accumulation of large masses of creep test data, are discussed.

Thermal Creep Design Criteria

Robert Goldin
Bell Aircraft Corporation

WITH THE ADVENT of flight involving aerodynamic heating, the problem of relating material allowables to use in structural design is abruptly and urgently reopened. This design element, together with operating-condition assumptions and safety-factor criteria, are the essential data which the structural analyst must have before he can determine hardware cross sections. Having these, the engineer can apply his complex analytical tools and answer the designer's question: "How thick must this element be?" This paper is primarily concerned with the criteria problem of what allowable data are to be used in relation to what loads in the analysis of heated structures. The problem is complicated in all areas—the establishment of limit condition combinations, the thermal condition stress analyses, the definition of primary material properties, and the physical accomplishment of material and structural tests. To convey basic concepts more clearly, examples used in this paper are drastically simplified; in actual design situations, the degree of simplification permissible is a matter of professional judgment for each particular problem.

In cold structures, the material properties used by the stress analyst are basically those shown in Fig. 1. These properties are used to confirm the fact that the structure will satisfy each of four different tests of adequacy—whichever is the more critical:

Yield Strength—ability to sustain a "limit" load magnitude without appreciable permanent deformation.

Ultimate Strength—ability to sustain a specified peak (design "ultimate") load without failure.

Fatigue Strength—ability to sustain a specified number of repetitions of load without failure.

Rigidity—ability to retain the desired structural shape within tolerable limits defined by various elastic criteria.

Each of the above represents specific elements of physical characteristics which determine adequacy of the performance of structures from various strength standpoints. Yield strength is required because a visibly distorted structure may be unserviceable and therefore is almost invariably condemned as unsafe. Ultimate strength is checked so that at least some margin will exist beyond required performance prior to occurrence of "catastrophic" failure. Fatigue strength is needed so that desired life endurance is achieved. And finally, rigidity is required so that mechanical interferences and adverse aeroelastic phenomena are avoided. In any specific structural element, very likely more than one of these four characteristics may closely govern the design. The fundamental physical material properties related to these are indicated in Fig. 1 for cold structures. The same comparisons are illustrated in Fig. 2 for hot structures.

STRENGTH CHARACTERISTIC	MATERIAL PHYSICAL PROPERTY	PARAMETERS MEASURED
YIELD	YIELD ALLOWABLE	STRESS AT 0.2% STRAIN SET
ULTIMATE	ULTIMATE ALLOWABLE	STRESS AT FAILURE
FATIGUE	S-N PROPERTIES	FAILING STRESS VS. CYCLES
RIGIDITY	MODULUS OF ELASTICITY	STRESS VS. STRAIN

FIG. 1. Design material properties for cold structures.

The criteria by which the above-described strengths are related to design loads and the material physical properties in cold aircraft design are generally well

STRENGTH CHARACTERISTIC	MATERIAL PHYSICAL PROPERTY	PARAMETERS MEASURED
YIELD	CREEP-SET ALLOWABLE	STRESS AT 0.2% CREEP-SET FOR VARIOUS TIME & TEMPS.
ULTIMATE	STRESS-RUPTURE ALLOWABLE	STRESS AT CREEP-RUPTURE FOR VARIOUS TIME & TEMPS.
FATIGUE	S-N PROPERTIES	FAILING STRESS VS. CYCLES FOR VARIOUS TEMPERATURES
RIGIDITY	MODULUS OF ELASTICITY	STRESS VS. STRAIN AT TEMP, ISOCHRONOUS STRESS-STRAIN CURVES

FIG. 2. Design material properties for heated structures.

Mr. Goldin is Chief Structural Design Engineer in the Aircraft Division.

understood and will not be discussed in detail here. A brief commentary, however, is in order because engineers at times proceed with structural design without consciously realizing that there are these four strengths to be considered. By far, the most popular characteristic for governing strength computations is ultimate strength (1.5 times limit load at failure), with which ultimate allowables or buckling strength is used. Sometimes, however, yield allowables of certain materials are about half of the ultimate allowables, and, in such cases, yield strength (usually the limit load compared with yield allowable) governs design. In much of missile structural design the factor-of-safety spread between required yield and ultimate strengths is further reduced or the ultimate requirement is omitted entirely, forcing yield strength to govern much more. Fatigue strength has become increasingly important but as yet remains a minor factor in determining cross-sectional areas and hence structural weight. The last aspect, rigidity, is becoming quite significant and especially in thin-wing and high-slenderness configurations is definitely governing structural design and airframe weight. In this case some governing tolerable deformation or rate of deformation becomes the criterion, and modulus-of-elasticity is the key material characteristic which governs structural size.

A great wealth of physical property data has been accumulated in documents such as ANC-5[1] for use by the stress analyst in checking for these four strengths. When the considerations of heating enter the picture, a serious disruption of the established precedents occurs due to the introduction of changes of these characteristics as a function of two new parameters—time and temperature. The name creep aptly personifies these; the effect of the two new parameters on each of the four design strengths is discussed in the following sections.

Creep and Allowable Yield Stress

In considering the criteria associated with permanent deformation or yield, there are a number of factors considered. First, permanent deformation many times involves geometric distortion which renders the component at least partially inadequate in accomplishing its intended function. Secondly, permanent deformation is characteristically taken as a sign that loadings above those used in design have been experienced and thereby "damaged" the structure. Thirdly, permanent deformation is also taken as a sign of weakness—in original design and also in that the structure may not be as capable of carrying design load as it was before such yielding occurred. Because of the last two factors, in normal service usage of any aircraft, inspection and maintenance practice demands that the aircraft be grounded whenever any yielding has become evident. It is for this reason that the Navy specifies, among other things, that, "Deformations remaining after application and removal of design-yield loads *shall not be noticeable upon inspection* . . ." (see paragraph 3.1.4 of MIL-A-8629, reference 2). However analytically irrational this may be, its practical necessity is inescapable since the mechanic who makes the ground inspection is not a structural engineer and may be incapable of separating visible minor yielding from serious yielding due to overload or inadequate strength.

Because of the foregoing practical considerations, it has in the past been possible to establish a criterion for the amount of yield to use in defining what a yield allowable shall be. Numerous calculations have been made of the amounts of geometric distortion that will result if structural elements (or outer fibers in bending) were to deform 0.5 per cent, 0.2 per cent, 0.1 per cent, and others. In a recent paper by Dukes and Padlog,[3] permanent sets of 0.1 to 0.2 per cent were found to be equivalent to a 10 per cent permanent set of a wing tip based on its elastic deflection under limit load. Hence in that case, a wing tip which deflects 10 ft. under load would have a permanent 1-ft. deformation if the creep (or yield) set were permitted to be 0.1 to 0.2 per cent. This was considered by the authors to be a maximum tolerable amount of deformation. In another recent study by Mathauser, Berkovitz, and Stein of the NACA,[4] the results of a study of creep-set calculations vs. wing-tip deflection set are presented. In this paper, for a constant-stress wing, it is assumed that 10 to 100 per cent set of the wing tip, as compared to its elastic deformation under design load, is the "range of interest" beyond which creep deflections are "excessive for most structural applications." It was shown that such permanent deformations are produced by creep (or yield) permanent sets of from 0.2 to 0.02 per cent.

From many studies such as the foregoing, the value for permanent yield set (or strain) selected as the basis for determining yield allowable stress was established many years ago as 0.2 per cent. The following quote is excerpted from ANC-5:

"Since permanent deformations of any appreciable amount are undesirable in most structures, it is customary to adopt an arbitrary amount of permanent strain that is considered admissible for general purposes. The value of this strain has been established by material testing engineers as 0.002 (0.2 per cent) . . . . Since the deformation due to creep has precisely the same external effects as those due to yield, it is logical to conclude that the arbitrary permissible creep set should also be taken as 0.2 per cent. It is nonetheless true that engineers are still interested in knowing what stresses, temperatures, and times will produce various values of creep strain, just as they like to see room temperature stress-strain curves of various materials—for detail compression instability studies and general research purposes. This is discussed further in a subsequent section of this paper. But for structural design purposes, however, they should be primarily interested in the 0.2 per cent creep-set data as shown in Fig. 3. This is not a new proposal, having been advanced by others such as Micks of the RAND Corporation,[5] but full appreciation of the practical reasonableness of this criterion has not yet occurred. Even in ANC-5, from which was extracted the logical quote given above,

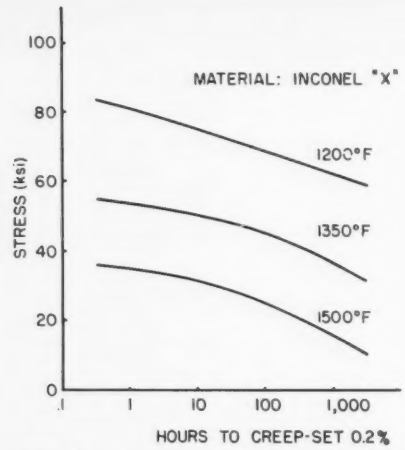

FIG. 3. Stress for 0.2 per cent set vs. time and temperature.

there is not provided creep-set data based on this criterion. Instead, it shows curves for creep for total deformation (elastic plus creep set) which normally is of lesser use to the structural engineer. As a matter of fact, the yield-set criterion of 0.2 per cent obviously results in different total deformations for steel and aluminum, because the elastic portion of the total set for steel is only one-third that of aluminum at the same stress.

Based on this discussion of yield and creep deformations, it is therefore proposed that the same material-allowable permanent deformation criterion be applied for design—namely, 0.2 per cent permanent set. Thus, for the design situations where permanent deformation is the governing factor, the criterion needed by the stress-analyst is defined for the great majority of cases. Material test engineers should always supply the creep curves based on this long-standing criterion as shown in Fig. 3, and, when the limit load-life-temperature conditions have been defined, the stress analyst then directly has the means for determining the cross-sectional areas needed to satisfy deformation strength requirements (when buckling is not involved). The occasional situation where some other more rational deformation criterion must be used may still arise, just as it does occasionally relative to establishing some other rationally permissible yield, but this probably affects as few as one stress calculation in a thousand or more.

In laboratory tests for adequacy for yield, the test would consist of simultaneously exposing the structure to a limit condition of load, temperature, and time under load and temperature. Adequacy of the structure is demonstrated by no appreciable yield being evident. A test factor-of-safety might be obtained by increasing the time of exposure to load and temperature and obtaining a ratio of the test time until yield occurred divided by required time. Time is used here so that the same specimen is rationally usable to complete the test. If load or temperature were to be used, the test should rightfully be rerun from the start with a new test specimen.

Creep and Allowable Ultimate Stress

By far, a more controversial design area is the problem of providing some ultimate strength level for heated aircraft structures. This problem was reviewed to some extent by this writer in an ASME paper in 1956[4] in relation to overall structural design criteria philosophy. These general considerations will not be repeated here in total, but a brief review is essential for clarification in relation to creep.

It has often been contended by many authorities in the field of criteria that the 1.5 factor of safety used in cold-structure design cannot be used realistically in more complicated design areas. Conventionally in cold-structure design, the limit load is used to find stress, the stress is multiplied by 1.5, and the result is compared with the ultimate material allowable to verify the required cross-sectional area (always for tension elements, sometimes for short-column compression). If buckling is involved, it is required by accepted criteria that 1.5 times the limit load be carried by the structure without experiencing catastrophic failure. If this concept were carried over to heated aircraft structures, it superimposes a drastic load conservatism on top of conservatism for time-duration of the design load, temperature of the structure at the time the design-load occurs, and total life of the aircraft. To compensate for these and still make it possible for the stress analyst to perform design calculations in a practical manner, some new criterion is needed relative to ultimate strength.

If it were desired to follow rationally the outdated present criterion, it would be necessary to proceed as follows in the design of heated structures. First, a limit-condition load would be set which represents a maximum expected load (or stress) at a certain temperature level. Second, the aircraft life would be assumed, and the time duration of the load and number of encounters during the life would be estimated, resulting in a time at a certain load and temperature. Third, the attempt would be made to obtain a material allowable which would represent experiencing the limit stress for the required total-time at temperature, followed by one loading to destruction. Finally, the stress analyst would then select a cross-sectional area which would make the last encountered failing load at least 1.5 times the limit, sustained load.

Obviously, the providing of allowable data which would satisfy the foregoing design procedure is completely impractical. Present creep stress-rupture curves are all plotted to provide the stress level which, if held for the entire time at load and temperature, will result in failure (see Fig. 4). What some analysts have therefore resigned themselves to doing is using that creep stress-rupture curve and calculating a cross-sectional area which results in a stress which is two-thirds less than the rupture allowable shown (thus allowing for the 1.5 ultimate factor of safety). This involves the implicit assumption that the design ultimate load has occurred every time that the limit load

was expected and that it was sustained for the length of time that the limit load endured. Such a conservatism is truly unthinkable in aircraft-design practice.

One method of avoiding such unrealistic practice advanced by this writer[6] and others is to discard at least partially the ultimate strength design requirement and design instead for yield at 1.15 times limit loads and perhaps require some slightly higher buckling condition factor of safety. This involves some unneeded safety factor and perhaps is a little severe. Another and possibly more realistic approach is as follows. First, continue designing for yield strength as described earlier in this paper using the conventionally conservative limit load-and-condition combinations. Second, in order to provide a margin of safety with respect to ultimate strength, arbitrarily raise the entire limit-load level by some reasonable factor considerably lower than 1.5 for the estimated temperature and total-life time duration. Third, having this fictitious higher load (and the temperature and time), enter creep stress-rupture curves such as shown in Fig. 4 and obtain an allowable ultimate stress. This is discussed somewhat by Dukes and Padlog in reference 3, and the creep-rupture factor of safety of 1.15 used therein is considered both ample and realistic by this writer.

The creep-rupture, or elevated-temperature failing-strength, criterion outlined above is practical both to the stress-analyst user and to the material-test data supplier. Already there are creep stress-rupture curves for most common materials at many temperatures and times in documents such as ANC-5. While there is unrealistic conservatism in assuming that this higher level of load occurs everytime that the limit-condition load occurs, the reduction of the level from 1.5 to 1.15 accomplishes a realistic compensation. In this writer's opinion, such a factor in a future structural-design specification would be unrealistically high if made greater than 1.25 and unrealistically low if made less than 1.10.

The laboratory test for adequate ultimate strength would consist of exposing the structure simultaneously to an ultimate condition of 1.15 times the limit-condition load, limit-condition temperature, and limit-condition design time under load and temperature. Adequacy of the structure is demonstrated by experiencing no failure. A test factor of safety might be obtained by increasing the time of exposure to load and temperature and obtaining a ratio of the test time until failure occurred divided by the required time. As discussed before in connection with yield strength, time is used here (rather than load or temperature) so that the same specimen is rationally usable to complete the test.

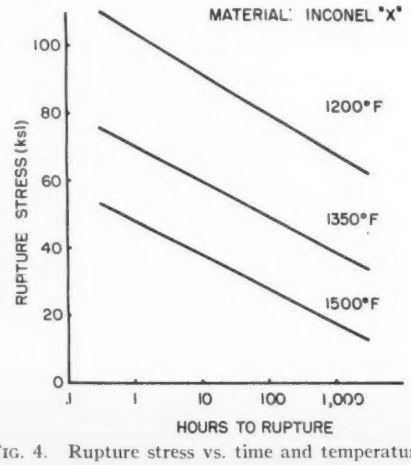

FIG. 4. Rupture stress vs. time and temperature.

STRESS RATIO $R = \frac{\sigma\ MIN}{\sigma\ MAX}$	STRENGTH INVOLVED	DESCRIPTION OF LOADING
+1	ULTIMATE YIELD	STATIC CONDITION LOAD
0	FATIGUE (COLD) CREEP (HOT)	ZERO TO TENSION LOAD
-1	FATIGUE	COMPLETE LOAD REVERSAL. PLUS, TO EQUAL MINUS, MAGNITUDE
∞	NORMALLY NOT CONSIDERED	ZERO TO COMPRESSION LOAD

FIG. 5. Types of fatigue load cycles.

ELEVATED-TEMPERATURE FATIGUE

From a designer's standpoint, perhaps the most obscure of the four strengths to deal with analytically is the fatigue strength problem. Fatigue refers, broadly speaking, to repeated application and removal of load. Therefore what has been discussed in the earlier portions of this paper could be classed as various types of fatigue loading since the loading involved generally will go from a zero or low stress value to a higher stress and back down again repeatedly. In a very real sense, therefore, what is done in creep analysis with respect to the ultimate strength criterion discussed above closely patterns what might be done in fatigue analysis. This writer has strongly believed that for conventional cold-airplane fatigue problems a design criterion similar to that outlined in the previous section of this paper (on ultimate strength) provides perhaps the only practical analytical design tool. This is discussed further in the following paragraphs.

In operating regime where appreciable thermal considerations enter the picture, the thing that characterizes creep problems from fatigue at-elevated-temperature problems is the degree of reversal of load. Fig. 5 presents a method of defining fatigue loadings as presented by the Batelle Institute in reference 7. R describes the variation of load level in a fatigue-cycling machine. It is seen that when stress ratio $R = +1$ (where minimum and maximum load are one and the same), a static unchanging condition exists and there is no load variation. If the time-at-temperature of this load is defined, then the stress analysis approach is to consider yield strength or ultimate strength as

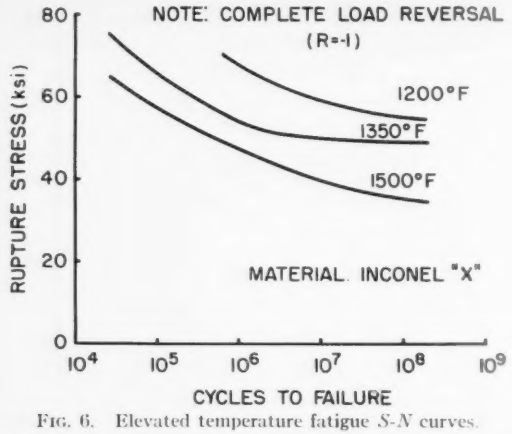

FIG. 6. Elevated temperature fatigue *S-N* curves.

described earlier. Similarly, under elevated temperature conditions it is generally believed that when $R = 0$ (where the minimum load is zero and the maximum load is some given value), the total time under a repeatedly applied load for most materials will generally be not too different from the total time under a static load of the same magnitude. On this basis, then, is the presumption almost invariably made that creep yield and failing strength can be determined by use of allowable curves such as Figs. 3 and 4 obtained from steadily held static load material tests.

When $R = -1$ (where complete reversal of load occurs and the maximum positive load equals the maximum negative load), the phenomenon of creep as commonly thought of does not occur. Creep in one direction very closely neutralizes creep in the other direction, and the failure achieved most closely resembles that which occurs in a room-temperature fatigue test. It is therefore quite reasonable to restrict most of the fatigue analysis and test effort in the heated-structures design regime to those cases where complete (or at least partial) load reversal occurs. In line with this, the heated-specimen fatigue *S-N* curves shown in ANC-5 are for complete load reversal conditions, and a recommended presentation of "allowables" data is as illustrated in Fig. 6.

As discussed earlier in this section on elevated temperature fatigue, it is strongly believed by this writer that a realistic analytical design criterion for fatigue is achieved by use of the same approach as that recommended for creep stress-rupture. Accordingly, the limit-condition loads in the fatigue loading spectrum would at all levels be multiplied by a factor such as 1.15, and the required design life number-of-cycles of loading (and associated temperatures) would then be applied at this increased level. If the fatigue loading could be simplified to an equivalent one-load level with complete reversal of a stipulated number of cycles at a single value of temperature, then a design allowable could be selected directly from curves as illustrated in Fig. 6 and a design for fatigue at elevated temperatures achieved. The safety factor to cover material and fabricating variations is then represented in the 15 per cent higher-than-anticipated level of loading (which in itself is invariably selected conservatively) throughout the entire life, and the required life is a fixed number. The laboratory test of the design is simply: Can the component sustain the design (1.15 times the expected limit condition) load spectrum at the limit-condition temperature without experiencing failure? The test factor of safety could be expressed by the ratio of actual life cycles achieved divided by required life cycles, as was done before in terms of time.

RIGIDITY

As indicated earlier, the primary parameter influencing rigidity is modulus of elasticity. This parameter is influenced primarily by temperature as illustrated in Fig. 7. In a sense, the criteria aspect is simpler because of the fact that in the past the criteria has not been related to the material modulus parameter itself. It may be defined by degrees of twist, inches deflection, or required EI and Gj. Therefore, if the load, the geometry, and the separately obtained criterion is given, then the appropriate modulus can be immediately picked from such plots as is shown in Fig. 7. In selecting the modulus, one normally would use the value determined for the highest temperature encountered with the operating condition for which the rigidity criteria were selected.

The above covers the broad area involving flutter, vibration, and other aeroelastic conditions. However, in connection with Ultimate Strength, modulus of elasticity *in combination* with yield (or creep) plays an all-important part in establishing buckling strength. Relative to this consideration, the 1.15 factor of safety discussed earlier provides the loading levels to be used with time and temperature. However, the "material allowables," if such a term can be used, are not provided by any of the previously presented curves.

In cold-structure instability analyses, the necessary tool is the complete stress-strain curve of the material

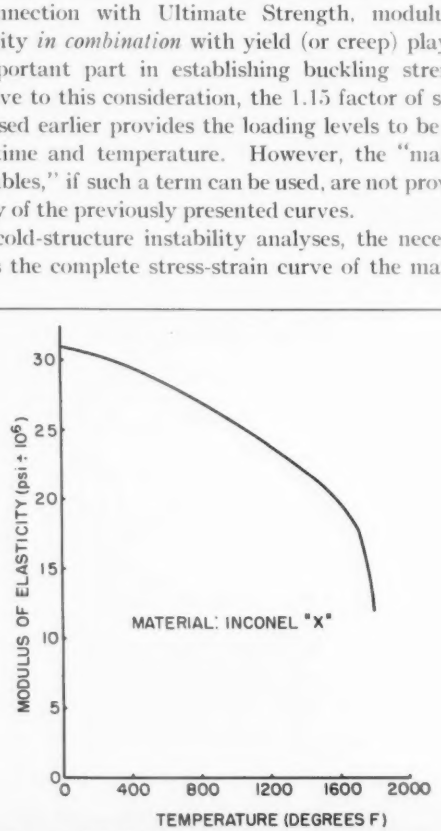

FIG. 7. Modulus of elasticity vs. temperature.

being considered. With this, and its simultaneous definition of elastic E and occurrence of permanent set, relatively accurate predictions can be made of the buckling stress. In hot structures, the equivalent data are provided in isochronous stress-strain curves such as is illustrated in Fig. 8. This introduces the time and temperature parameters, in addition to stress, needed to define creep—which influences buckling in exactly the same way as does cold-material yield. Accordingly, in addition to the data represented in Figs. 3, 4, 6, and 7, the materials-testing engineers will have to supply stress analysts with isochronous stress-strain curves such as in Fig. 8.

The laboratory test for adequate rigidity is accomplished by subjecting the structural component to a limit condition of load, temperature, and in some cases, time under load and temperature. Test adequacy is demonstrated by not exceeding the deformation criterion which governs the design. The test factor of safety can be expressed in the ratio of the allowable twist, displacement, etc., divided by the actual test value. The rigidity conditions which relate to inherent structural instabilities only are checked by the same test criteria as are used to demonstrate ultimate strength (as defined in an earlier section).

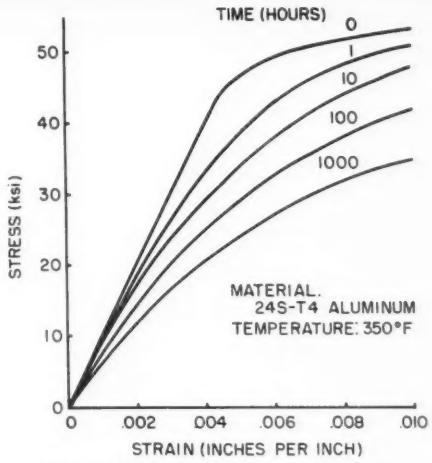

FIG. 8. Isochronous stress-strain curves.

CONCLUSIONS

In this paper, elevated temperature criteria have been presented which are needed by the stress analyst in translating limit load-temperature-life conditions and material property (or allowable) data into actual cross-sectional areas of structural elements. Definition of the complex design limit load-temperature-life conditions is not attempted at this time; the basic ground rules for making such definitions have been set forth in a previous paper by this writer.[6] Similarly, the intricate analytical theories and tools required in making the necessary calculations are not discussed herein, having been the subject of papers by numerous specialists in that field. The criteria presented embrace the four basic types of strength which the structural engineer is concerned with—namely, yield strength, ultimate strength, fatigue strength, and rigidity. The types of material data needed are described, and the associated laboratory test criteria to verify adequacy of the structure are defined.

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NATIONAL MIDWESTERN MEETING ON GUIDED MISSILES

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The Meetings Committee plans to schedule sessions on Astronautics, Propulsion, Aerodynamics and Ballistics, Structures and Aerodynamic Heating, Guidance and Control, Operation's Analysis, Composite Design, and Engineering Management in Missile Development.

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Stable Platforms for High-Performance Aircraft

A discussion of translational vibration in relation to platform tilt and an analysis of the kinematic rectification of platform and gyro motions.

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A STABLE PLATFORM is an apparatus used by self-contained air-navigation systems for maintaining a reference direction angularly fixed in space. The primary member is a stable element mounted in gimbals to provide angular freedom from the carrying vehicle and bearing inertial instruments whose signals are used to enforce fixity of the element despite disturbing influences of the vehicle.

Stable platforms of a sort have been in use for many years. For example, the 16-in. gun turrets on a battleship and the gyro vertical in the instrument panels of commercial aircraft both have the feature of maintaining their orientation, approximately, despite motions of the carrier. But the great accuracy required for modern self-contained navigation puts autonavigator platform stabilization in a class quite apart from previous applications.

Consider, for example, the requirements of an inertial navigation system. Such a system determines velocity and position by sensing and integrating vehicle accelerations.[1] Because any device which senses an inertial force due to acceleration will also sense the force of gravity, the system can function only if the direction of gravity is accurately known, so that it may be removed from the total acceleration. Just how accurately the vertical must be known can be appreciated by considering that the stable element is utilized as a sort of substitute for the sun and stars of celestial navigation. A platform drift of 1° of arc is as if a navigation star had shifted 1° of arc, and an error of the order of 60 nautical miles at the earth's surface can result.

To be of practical use then, the stable element must "stay put" within very close limits. It must do so, in some cases, in an environment which is quite unfavorable for instruments—a high-performance airplane or missile may make all manner of maneuvers and abrupt changes of velocity and is likely to provide a severe temperature and vibration climate.

The Stabilization Problem

If a platform could be devised which was perfectly balanced and which was mounted on bearings having absolutely no friction (and protected from air currents, magnetic coercion, etc.), then the problem of a stable reference would be solved once and for all because no movement of the carrying vehicle could induce such a platform to change its orientation.

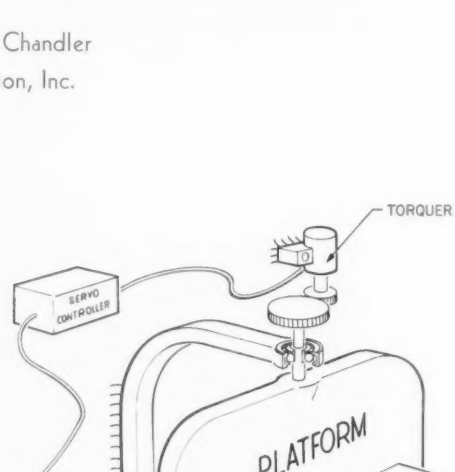

FIG. 1. Single-axis platform.

Since practical achievement of such an arrangement is still rather remote, additional measures must be adopted for maintaining platform fixity. These invariably involve sensing spatial rotation of the stable element and applying a corrective torque to the element. A typical arrangement is shown in Fig. 1 for control of a single platform axis.

(In practice, gyroscopes are used as "dip sensors" to measure rotation of the stable element, and, in some applications, they also provide the dynamic restoring torque directly. In a typical navigation system, however, the gyroscopes are small compared to the element to be stabilized, and the gyroscope signals are used to control platform-torquing mechanisms.)

Dip Sensors

The critical member of a platform control system is the dip sensor, an inertial device whose mechanical output indicates the dip of the platform. For this, one

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might think of using an inert mass mounted on precision bearings (Fig. 2a) and so protected from disturbing influences that it simply remains immovable in space. As a practical matter, however, the necessary low-friction, balance, and isolation requirements are as yet unachievable.

One turns, then, to the gyroscopic principle that a rotating mass has a much stronger tendency to maintain its orientation than an inert mass of comparable size. A common arrangement for a gyroscopic dip meter involves isolating the rotating wheel from the platform by a set of two gimbals (Fig. 2b). For this arrangement the output axis of the gyroscope might indeed be oriented as indicated in Fig. 1, the gyroscope remaining fixed in space, the platform rotating around it, and the pickoff measuring the motion (i.e., the dip) of the platform with respect to inertial space.

Alternatively, the gyroscopic principle may be employed as indicated in Fig. 2c. Here the wheel is mounted to the platform through a single gimbal in such a way that motions of the platform apply to torque to the wheel and cause it to precess. In this case, the mechanical output of the gyroscope is in a direction normal to its spin axis and to the axis of the input motion—e.g., the gyroscope output axis would be horizontal in Fig. 1. From the standpoint of producibility, the single-axis gyroscope is much more attractive than its two-axis counterpart because it requires only one high-quality (essentially friction-free) bearing—the output-axis bearing in Fig. 2c—while the gyroscopic dip meter of Fig. 2b requires two such high-quality bearings in series.

The performance of the bearings in gimbaled gyroscopes is greatly improved by floating the assembly of moving parts in a fluid of equal density so that the bearings need support only a few per cent of the total weight. In this respect, the effects of temperature variation on the fluid, together with certain mass shift effects, make the design of good environmental enclosures an important part of the stable platform problem.

An old, and potentially very attractive, idea is the so-called free-rotor gyroscope* in which the rotating mass is spun freely on spherical pads—e.g., using gas lubrication—as shown in Fig. 2d. A two-axis pickoff is arranged to sense wander of the spin axis of the mass thus indicating platform dip about two orthogonal axes. It might be expected that application of this elegant instrument in stabilizing platforms would be accompanied by challenging problems in precision design.

The instruments represented in Fig. 2a, b, and d all remain spatially fixed and (ideally) are themselves unaffected by platform motions. But the single-axis gyroscope of Fig. 2c precesses in response to platform dip so that its dynamic characteristics may strongly affect the control system. If, for example, the gimbal bearing is considered frictionless and no damping is introduced, the summation of torques about the gyroscope output axis (pickoff axis in Fig. 2c) is

$$I(d^2\theta/dt^2) = H(d\phi/dt) \qquad (1)$$

in which I is the moment of inertia of the gyroscope about its output axis, θ is the precession of the gyroscope, H is the angular momentum of the gyroscope wheel, and ϕ is the platform dip about the vertical axis in Fig. 1. It is seen that in this case the gyroscope precession angle reports the integral of the platform dip angle. If the platform sits off null, the gyroscope precesses at a constant rate; if the platform makes an excursion off null and returns, the gyroscope ends up in a precessed position.

But if heavy damping, C, is introduced about the output axis, Eq. 1 becomes

$$I\,(d^2\theta/dt^2) + C\,(d\theta/dt) = H\,(d\phi/dt) \qquad (2)$$

so that, with an appropriate ratio of C to I, gyroscope precession θ can again be made directly proportional to platform dip ϕ for all motions of concern.

Because it integrates platform dip, the undamped single-axis gyroscope effects a control system which will permit absolutely no constant dip angle of the platform from the orientation which the gyroscope considers neutral. That is, the nulling error of the system does not, in this case, depend upon the threshold sensitivity of the gyroscope or the electrical "gain" of the servo. On the other hand, using a heavily damped gyroscope leads to a simpler control loop. In practice, the choice of damping is generally made upon operational considerations.

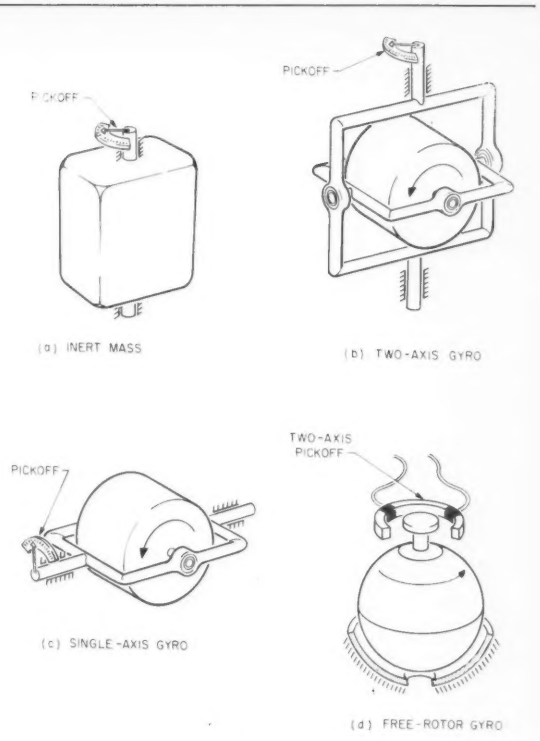

FIG. 2. Dip sensors.

* U.S. Patent No. 1,984,874, December 18, 1934, R. E. Gillmor *et al.*

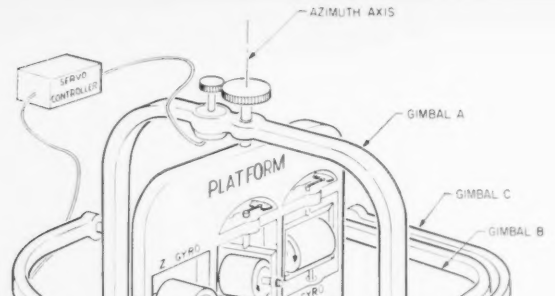

FIG. 3. Three-axis platform.

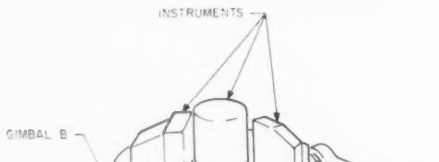

FIG. 4. Internal gimbaling.

The Control Loop

The initial consideration in implementing the control arrangement of Fig. 1 is to be sure that the system is stable. If the dip sensor reads dip angle directly and if "proportional control" is employed, then the stability picture can be seen to a close approximation by noting that the control system reacts upon the platform in exactly the same manner as a torsional spring—that is, a restoring moment is exerted by the torquer which is exactly proportional to the magnitude of the platform dip. It is well known that the natural motion of an undamped mass-spring system is an undamped sinusoid which, of course, does not represent a sufficiently stable arrangement. With an actual uncompensated controller, moreover, the restoring torque would in fact be slightly "late," so that the oscillations might be expected to diverge. The situation is readily corrected by including a lead network in the servocontroller—i.e., an electrical differentiation which allows the control system to anticipate platform movements and to apply its corrective torque preveniently instead of ex post facto. The result is a system which may be given any degree of stability desired.

Stability of the control loop could have been achieved alternatively by including mechanical damping in the bearings. This is quite undesirable, however, because motions of the airframe could then induce large torques upon the platform through the bearings.

When the dip sensor does not read dip angle directly, additional compensation may be required. For example, if single-axis gyroscopes of the true integrating variety are employed, there is introduced into the control loop a large additional lag (90° in the case of sinusoidal motion) wh'ch must be compensated electrically in the servocontroller.

In addition to effecting stable control of the platform, the servosystem must hold oscillatory excursions within definite bounds to ensure proper operation of instruments. (In particular, single-axis gyroscopes themselves must be held closely to their nominal orientation for proper operation.) The ability of the servo to hold platform motions within bounds in the face of disturbing torques is known as the "stiffness" of the servo. At very low frequencies, this stiffness may be infinite for a true integrating gyroscope and need be bounded only by practical limits on electrical gain for proportional sensors —e.g., two-axis, or heavily damped single-axis gyroscopes. At very high frequencies the inertia of the platform itself adequately resists disturbing torques. Between these extremes, in the vicinity of the natural frequency of the mass-spring system which is the control system, adequate stiffness depends upon good design of the electrical characteristics of the controller.

Beyond the linear region of torquer operation, the effective stiffness of the control loop decreases as the torquer becomes progressively saturated. Sufficient torque capacity must be made available so that this loss in stiffness does not result in intolerably large platform angular motion in the presence of maximum expected disturbances.

Above all, steady drift of the platform must be held within the limit specified by navigational requirements. In this, the dip sensor is the sole determinant: ultimately, the accuracy of the entire navigation system depends upon the drift characteristics attending its gyroscopes.

Three-Axis Control

The single-axis platform of Fig. 1 can be converted to a three-axis platform by adding gimbals to give freedom about the other axes and by adding gyroscopes to control them. A typical arrangement is shown in Fig. 3. Three single-axis gyroscopes are mounted with their input axes mutually orthogonal. Torquers are mounted between the gimbals, and each is controlled by the appropriate gyroscope.

Specifically, the Z gyro always senses rotation of the platform about the azimuth axis and always instigates

a torque between the platform and gimbal A. For an arbitrary airplane heading, platform dip about the roll axis is sensed partly by the X gyro and partly by the Y gyro. The X and Y gyro signals are combined appropriately by a resolver (mounted between the platform and gimbal A), and the resulting signal is used to control the torque applied between gimbals A and B. The X and Y gyro signals are combined also to indicate platform motion about the pitch axis and to control a corrective torque between gimbals B and C.

It is noted that the platform in Fig. 3 actually has four degrees of angular freedom with respect to the airframe, instead of three. The redundant gimbal is employed because it is highly desirable to maintain gimbal axes mutually orthogonal (approximately) to avoid inertial coupling between the gimbals and (in the extreme) to avoid gimbal lock. To this end, gimbal C, known as a follow-up gimbal, is torqued with respect to the airframe in response to a simple pickoff which measures relative motion between gimbals A and B.

The redundant gimbal scheme of Fig. 3 leads to an interesting situation when the vehicle pitches more than 90° of arc e.g., during an Immelmann maneuver by an interceptor. Just as the roll axis carries gimbal C through vertical, the entire gimbal system flips 180° of arc about the platform. This maneuver, for systems which must accommodate it, invokes the peak acceleration requirement for the gimbal torquing system.

One is, of course, at liberty to orient the system of Fig. 3 with respect to the airframe in any way desired. The first consideration is for the maneuvers the aircraft is to perform. The arrangement shown in Fig. 3 is usually the most expedient for interceptor aircraft which are likely to indulge in "barrel rolls" more frequently than in "Immelmanns." For such aircraft two sets of slip rings are required to connect the instruments on the stable element with their external equipment: one set between the platform and gimbal A, and another between gimbal C and the airframe. For aircraft which are restricted from 360° of arc maneuvers in bank and pitch, only one slip ring (azimuth) is required, "wind up" leads being adequate at the other gimbal junctions. If the bank angle is restricted to less than 90° of arc and the pitch angle is not, it would be expedient to interchange the roll and pitch axes in Fig. 3 and thus avoid gimbal flipping altogether.

When single-axis gyroscopes are used to stabilize a three-axis platform, as in Fig. 3, an additional type of interaxis coupling exists because the gyroscope pickoff is unable to distinguish between precession of a gyroscope and motions of the platform about the gyroscope output axis. Thus the pickoff signal of the Z gyroscope in Fig. 3 is $\sigma_z = \theta_z - \phi_y$. Similar expressions hold for the other pickoffs, so that each torquer is responding not only to the proper signal from its own axis but also to a signal from another axis. In certain frequency ranges the amplitudes of θ and ϕ are comparable so that the servosystem must definitely be designed on a three-axis rather than a single-axis basis.[2]

For a given navigation system the relative alignments of specific instruments on the stable element will be critical, and techniques must be developed for establishing them.

Design for an Aircraft Environment

In a slow-moving aircraft whose maneuvers are gradual, the task of the stable platform is not much different from that in a laboratory environment, and the system performance is dependent largely on the drift characteristics of the gyroscopes.

In a high-performance interceptor or guided missile, rapid maneuvers of the craft and the high vibration levels which generally result from high-speed aerodynamic disturbances and large power plants can produce severe disturbing torques on the stable platform. Moreover, the installation requirements for such aircraft call for lighter structural members, limited shock-mount excursions, and more elaborate temperature control equipment, each of which makes more difficult the problem of coping with airframe vibrations.

Space Economy

The stringent space limitations in operational aircraft demand that the most compact platform arrangement be sought. Sometimes an external gimbal arrangement similar to that shown schematically in Fig. 3 leads to the most efficient packaging of the platform elements. (This is particularly true if the arrangement is such that the main platform carries only a set of gyroscopes, the other instruments being mounted separately in some way.)

Many times, however, the number and shapes of the instruments to be mounted are such that it is expedient to mount them in two clusters. When this is the case, it is usually advantageous to use an internal gimbal system, such as that shown in Fig. 4. The utility of such an arrangement is clear, for example, in the case of a star-tracking system in which the telescope equipment might be mounted on the upper table and the stabilizing gyroscopes on the lower table.

In this arrangement the two tables are connected by a solid post. Gimbal A of Fig. 3 becomes a small sleeve surrounding the post in Fig. 4 and within which the entire table assembly is free to rotate in azimuth. Gimbal B now becomes simply a split beam (Fig. 4), which also lies within the diameter of the table assembly. Only the follow-up gimbal, C, is now external to the platform. Because of the follow-up action, the relative motion between internal gimbals A and B may be restricted to just a few degrees.

Often the arrangement of Fig. 4 can be made to occupy a much smaller volume than could an external gimbal arrangement for the same set of instruments.

Effects of Disturbing Torques

When the disturbing torque on the platform is steady (in one direction) over a period of time, required fixity of the platform is maintained by the servo which exerts a compensating torque on the platform. (If a true in-

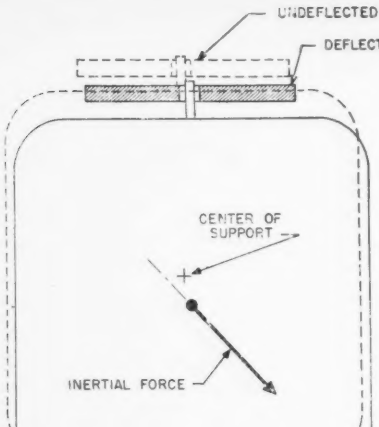

FIG. 5. Torque due to nonisoelasticity.

tegrating gyroscope is the controlling sensor, the platform will be maintained under steady disturbance with zero departure from null.) But, in addition, appropriate rigidity of the platform structure between instruments must be supplied, or unacceptable misalignments will occur under steady acceleration.

In the case of vibratory disturbances, the platform controller will permit some magnitude of platform dip, depending upon the stiffness of the servo at the disturbance frequency (as discussed above). For any given torquer, there will be some torque level at which the control gain is effectively reduced to an unacceptably low value. Thus, a definite upper bound exists on the disturbing torque which can be sustained by the system.

At a much lower level, oscillatory disturbing torques of a sustained nature can produce continuing oscillations of the platform about more than one axis. If these oscillations have a certain phase relationship, they can induce a rectification type of drift in the instruments carried.

An interesting exemplification of this phenomenon can take place in the single-axis gyroscopes themselves.[3] Consider, for example, a situation in which the platform in Fig. 3 is vibrating simultaneously about the roll and pitch axes. The pitch vibration causes the Y gyroscope to precess back and forth with respect to the roll axis. At an instant when the gyroscope is at the peak of its excursion, the rolling motion is at a maximum velocity. A component of the rolling motion is normal to the (deflected) momentum vector of the gyroscope and therefore produces a torque on the gyroscope. At the other extreme of the gyroscope swing, the rolling is in the opposite sense, but the component normal to the gyroscope momentum vector is now in a direction to produce the same resultant torque on the gyroscope as before. The result is a varying sinusoidal torque on the gyroscope which has an average value and which therefore produces a steady drift of the entire system.

The determining factor in prescribing platform servo stiffness may well be the tolerance on rectification drift.

Disturbance Mechanisms

There are numerous mechanisms by which aircraft maneuvers and airframe vibrations can induce disturbing torques on the stable element. One thinks, for example, of torques produced by gimbal bearing friction as the airframe rotates about the platform and of the inertial torque produced when an unbalance exists on a lineally accelerated platform. The best available bearing techniques must be used. For example, bearing alignment may be improved by designing the bearing and journal structure to ensure matched deflections under loading. Dynamic, as well as static, balance must be considered, or inertial interaxis coupling may become serious (in the same way that it is serious in high-density-airplane dynamics). The ideal solution to the "cross-product-of-inertia" problem is to achieve a nearly "iso-inertial" configuration of the platform elements.

Of a more subtle nature are torque-producing mechanisms which involve flexibility of the platform structure. For example, in building an external gimbal system such as Fig. 3, it is necessary in practice to make the gimbals much wider than those shown to achieve sufficient torsional stiffness of the gimbals. It is not feasible, however, to make the gimbals thicker at the same time because of the large increase in overall dimension which would be incurred. As a result, the gimbals are highly nonisoelastic—i.e. they are much more limber in one direction than in another—so that when the assembly is subjected to acceleration the inertial force on the platform causes it to deflect as shown in Fig. 5. If the direction of the acceleration is not along a principal axis of the gimbal, the gimbal deflection is not along the line of action of the force, so that the force may be applied at a significant moment arm with respect to the center of support of the gimbals. Influential torques are produced in this manner.

When internal gimbals are used, the entire assembly can be made isoelastic so that the mechanism just described is avoided. On the other hand, the central post connecting the two tables in Fig. 4 must be made quite stiff or a different sort of torque-producing mechanism illustrated in Fig. 6 can exist; for if the post is limber, accelerations of the center of the post will cause the tables to tilt. If the acceleration is steady or varies at a

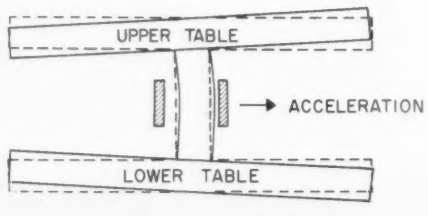

FIG. 6. Post bending.

low frequency, the platform servosystem will actually maintain the gyroscope-carrying table level, thus allowing the other table to oscillate. At high frequencies, where fixity is maintained by the inertia of the platform rather than by the servos, the tables will tilt equally (Fig. 6). (At frequencies above the structural natural frequency of the post-table combination, the tables will, of course, not tilt and the post will simply flex between them.)

Platform motions produced by either flexibility mechanism—nonisoelastic flexure or post bending—can result in torquer saturation or unacceptable rectification drift unless the necessary combination of torquer capacity and gimbal and servo stiffness is provided. (As a practical matter it is simpler to stiffen the post of an internal gimbal system than to stiffen external gimbals in the diametric direction.)

Vibration Control

The most straightforward measure for controlling the effects of airframe disturbances is, of course, effective shock-mounting.

It would be most desirable if the natural frequency of the shock mount could be made very low so that high-frequency disturbances would be attenuated by a maximum factor. However, one is faced immediately with a limitation on the excursion the mount may have during steady accelerations. This factor places a definite lower limit on the natural frequency of a passive shock mount.

In designing the mount, careful attention must be given the dynamic interaction between the mount itself and the flexible members of the platform structure. For example, if the outer gimbal in Fig. 3 or 4 carries a heavy mass, a secondary platform resonance results (involving the vibration of the gimbal mass and the stable element mass in opposite directions) which can lead to intolerably high transmissibility at some high frequency—e.g., 50 cps.

If the vibration climate is extreme and the excursion limits severe, it may be necessary to employ an "active"—e.g., hydraulic—shock mount whereby the natural frequency will not be bound by the excursion limit.

Flotation of the entire stable element is a more bold approach to the problem of effective environmental isolation. This measure will, of course, introduce a number of new technical problems.

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A method of determining augmentation of high-performance aircraft to reduce inherent susceptibility to inertia coupling

The Roll Coupling Problem—A Mathematical Approach

R. Westerwick
Convair, A Division of General Dynamics Corporation

TO UNDERSTAND better the phenomenon of inertia or roll coupling, Convair undertook a mathematical analysis, using only linearized airplane equations of motion and the predominant cross-coupling terms.

The physical aspects of the problem appeared with the modern interceptor type of aircraft, where the body weight is concentrated about the longitudinal axis of the airplane. It was found that the aircraft acted normally in rolling maneuvers until a certain roll rate was reached. At this point, the aircraft appeared to go out of control, assuming exceedingly large angles of attack and angles of sideslip. Several experimental aircraft were lost because of the excessive lateral or longitudinal loads resulting from the large maneuvering angles encountered during rolling maneuvers.

This violent coupling maneuver was predicted by W. H. Phillips in his now famous NACA publication, TN1627. However, it was not until the maneuver was encountered in flight that aircraft designers began to realize that the configuration trends had finally brought aircraft into the critical region. When this was demonstrated by the loss of airplanes and pilots, an accelerated program was initiated in an attempt to alleviate the problem. Convair also wanted to determine if it would be possible to redesign the airplane physically in order to effect a solution or if it would be necessary to use some type of automatic control to obtain a reasonable maneuver.

METHOD OF SOLUTION

It was decided to use the equations which express five degrees of freedom of the airplane. The velocity equation was considered to be inconsequential to the presence of the inertia coupling problem. It was further assumed that gravity had no effect on the presence, or absence, of the coupling. Assuming that it is possible to write the equations in the form of small perturbations about some steady-state value (designated by the subscript "o"), the equations are:

$$s\beta + (\dot{\psi}_o + \dot{\psi}) - \dot{\phi}\alpha - \dot{\phi}_o\alpha - \dot{\phi}\alpha_o - \dot{\phi}_o\alpha_o = Y_\beta(\beta + \beta_o) + Y_{\delta r}(\delta r + \delta r_o),$$

$$s\alpha + \dot{\phi}\beta + \dot{\phi}_o\beta + \dot{\phi}\beta_o + \dot{\phi}_o\beta_o - (\dot{\theta} + \dot{\theta}_o) = Z_\alpha(\alpha + \alpha_o) + g/v + Z_{\delta e}(\delta_e + \delta e_o),$$

$$s\dot{\phi} + (\dot{\theta}\dot{\psi} + \dot{\theta}_o\dot{\psi} + \dot{\theta}\dot{\psi}_o + \dot{\theta}_o\dot{\psi}_o)\,[(I_z - I_y)/I_x] - (I_{xz}/I_x)\,(s\dot{\psi} + \dot{\phi}\dot{\theta} + \dot{\phi}_o\dot{\theta} + \dot{\phi}\dot{\theta}_o + \dot{\phi}_o\dot{\theta}_o) =$$
$$L_\beta(\beta + \beta_o) + L_p(\dot{\phi} + \dot{\phi}_o) + L_r(\dot{\psi} + \dot{\psi}_o) + L_{\delta a}(\delta a + \delta a_o) + L_{\delta r}(\delta r + \delta r_o),$$

$$s\dot{\theta} + (\dot{\phi}\dot{\psi} + \dot{\phi}_o\dot{\psi} + \dot{\phi}\dot{\psi}_o + \dot{\phi}_o\dot{\psi}_o)\,[(I_x - I_z)/I_y] + (I_{xz}/I_y)\,(\dot{\phi}^2 + 2\dot{\phi}_o\dot{\phi} + \dot{\phi}_o{}^2 - \dot{\psi}^2 - 2\dot{\psi}\,\dot{\psi}_o - \dot{\psi}_o{}^2) =$$
$$M_\alpha(\alpha + \alpha_o) + M_q(\dot{\theta} + \dot{\theta}_o) + M_{\delta e}(\delta e + \delta e_o),$$

$$s\dot{\psi} + (\dot{\phi}\dot{\theta} + \dot{\phi}_o\dot{\theta} + \dot{\phi}\dot{\theta}_o + \dot{\phi}_o\dot{\theta}_o)\,[(I_y - I_x)/I_z] - (I_{xz}/I_z)\,(s\dot{\phi} - \dot{\theta}\dot{\psi} - \dot{\theta}_o\dot{\psi} - \dot{\theta}\dot{\psi}_o - \dot{\theta}_o\dot{\psi}_o) =$$
$$N_\beta(\beta + \beta_o) + N_p\,(\dot{\phi} + \dot{\phi}_o) + N_r(\dot{\psi} + \dot{\psi}_o) + N_{\delta r}(\delta r + \delta r_o)$$

where s is the Laplace operator.

It should be noted that in the above equations

$$\dot{\beta}_o = \dot{\alpha}_o = \ddot{\phi}_o = \dot{\theta}_o = \dot{\psi}_o = 0$$

These equations may now be divided into two sets of equations. These two sets will be called the steady-state equations (those equations involving terms with the subscript o) and the stability equations (which are the terms of the incremental variations about the steady-state values). The second-order terms are considered to be negligible as compared to the first-order variations in the stability equations, and for this reason are omitted.

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The steady-state equations are:

$$\dot{\psi}_o - \dot{\phi}_o\alpha_o = Y_\beta\beta_o + Y_{\delta r}\delta r_o$$

$$\dot{\phi}_o\beta_o - \dot{\theta}_o = Z_\alpha\alpha_o + g/v + Z_{\delta e}\delta e_o$$

$$\dot{\theta}_o\dot{\psi}_o[(I_z - I_y)/I_x] - \dot{\phi}_o\dot{\theta}_o(I_{xz}/I_x) = L_\beta\beta_o + L_p\dot{\phi}_o + L_r\dot{\psi}_o + L_{\delta a}\delta a_o + L_{\delta r}\delta r_o$$

$$\dot{\phi}_o\dot{\psi}_o[(I_x - I_z)/I_y] + (\dot{\phi}_o^2 - \dot{\psi}_o^2)\,(I_{xz}/I_y) = M_\alpha\alpha_o + M_q\dot{\theta}_o + M_{\delta e}\delta e_o$$

$$\dot{\phi}_o\dot{\theta}_o\,[(I_y - I_x)/I_z] + \dot{\theta}_o\dot{\psi}_o(I_{xz}/I_z) = N_\beta\beta_o + N_p\dot{\phi}_o + N_r\dot{\psi}_o + N_{\delta r}\delta r_o$$

The stability equations are:

$$s\beta + \dot{\psi} - \dot{\phi}_o\alpha - \dot{\phi}\alpha_o = Y_\beta\beta$$

$$s\alpha + \dot{\phi}_o\beta + \dot{\phi}\beta_o - \dot{\theta} = Z_\alpha\alpha$$

$$s\dot{\phi} + (\dot{\theta}\dot{\psi}_o + \dot{\theta}_o\dot{\psi})\,[(I_z - I_y)/I_x] - (I_{xz}/I_x)\,(s\dot{\psi} + \dot{\phi}_o\dot{\theta} + \dot{\phi}\dot{\theta}_o) = L_\beta\beta + L_p\dot{\phi} + L_r\dot{\psi}$$

$$s\dot{\theta} + (\dot{\phi}\dot{\psi}_o + \dot{\phi}_o\dot{\psi})\,[(I_x - I_z)/I_y] + (I_{xz}/I_y)\,(2\dot{\phi}_o\dot{\phi} - 2\dot{\psi}_o\dot{\psi}) = M_\alpha\alpha + M_q\dot{\theta}$$

$$s\dot{\psi} + (\dot{\phi}\dot{\theta}_o + \dot{\phi}_o\dot{\theta})\,[(I_y - I_x)/I_z] - (I_{xz}/I_z)\,(s\dot{\phi} - \dot{\theta}_o\dot{\psi} - \dot{\theta}\dot{\psi}_o) = N_\beta\beta + N_p\dot{\phi} + N_r\dot{\psi}$$

To determine if an airplane will be roll divergent for a particular flight condition, these equations are solved in terms of the function s. If any root is positive, the airplane is unstable at the rolling rate $\dot{\phi}_o$ and that flight condition.

By using coefficients which appeared to be representative of present-day interceptors, it was possible to solve the stability determinant. However, in order to solve and plot the roots of the equations more easily, an analog computer circuit was devised which would factor the fifth-order equation in s and give as results

$$(s + a_1)\,(s^2 + a_2s + b_2)\,(s^2 + a_3s + b_3)$$

An additional circuit was then added which resolved the quadratic terms $s^2 + \alpha s + \beta$ into their real and imaginary roots in terms of s, that is $(s + x + jy)$ $(s + x - jy)$. A plot was then made of the three distinctive roots: $(s + a)$, $(s + x_2 + jy_2)$, and $(s + x_3 + jy_3)$.

The plot which was used is a normal imaginary plane plot of roots except that it was extremely difficult to keep the roots along the real axis separated and clear with changing roll rates. To facilitate clearness, the roots which were on the real axis were plotted upon a plane of real axis versus $\dot{\phi}_o^2$. This was done only for the roots along the real axis.

The plot of the roots as a function of $\dot{\phi}_o^2$ is shown in Fig. 1 for a typical flight condition where the airplane becomes neutrally stable. In this plot are essentially three loci. The first which starts at $-0.54 + 2.16j$ is the plot of one of the longitudinal roots, the other would start at $-0.54 - 2.16j$. Because it is the mirror image of the root shown, it is not plotted. The second locus, which starts at $-0.08 + j\,1.37$, is the plot of one of the complex lateral roots. Again, the other complex lateral root is not shown because it is a mirror image. The locus starting at -1.54 is the real lateral root.

In order to determine the effect of changing several of the aerodynamic derivatives, Figs. 2 and 3 were plotted which show the effects of changing Cm_α and Cn_β. A plot of changing Cl_β was also made; however, the effect of this change appeared to be secondary.

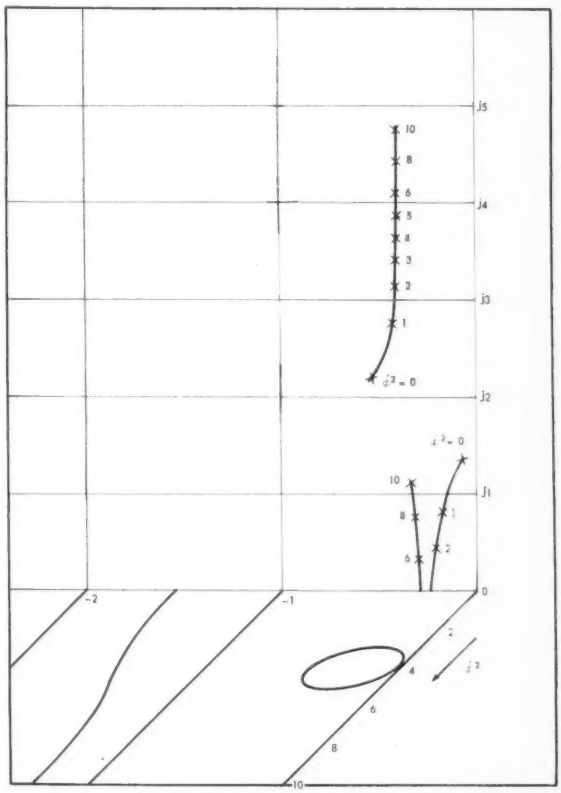

FIG. 1. Plot showing locus of roots of the stability equations as functions of the square of the roll rate.

The interpretation of these curves is that, if the curve at any time crosses over to a positive value of x, then the airplane will be roll divergent at this value of $\dot{\phi}_o$, and the value of all the variables will increase until the value of $\dot{\phi}_o$ is reached where the curve again returns to the negative side of the y axis.

By examining Figs. 1, 2, and 3, it appears that the conclusions reached by Phillip are valid. These conclusions may be stated as: Change Cn_β and Cm_α such that the natural frequency in pitch approaches the natural frequency in roll. For the average interceptor

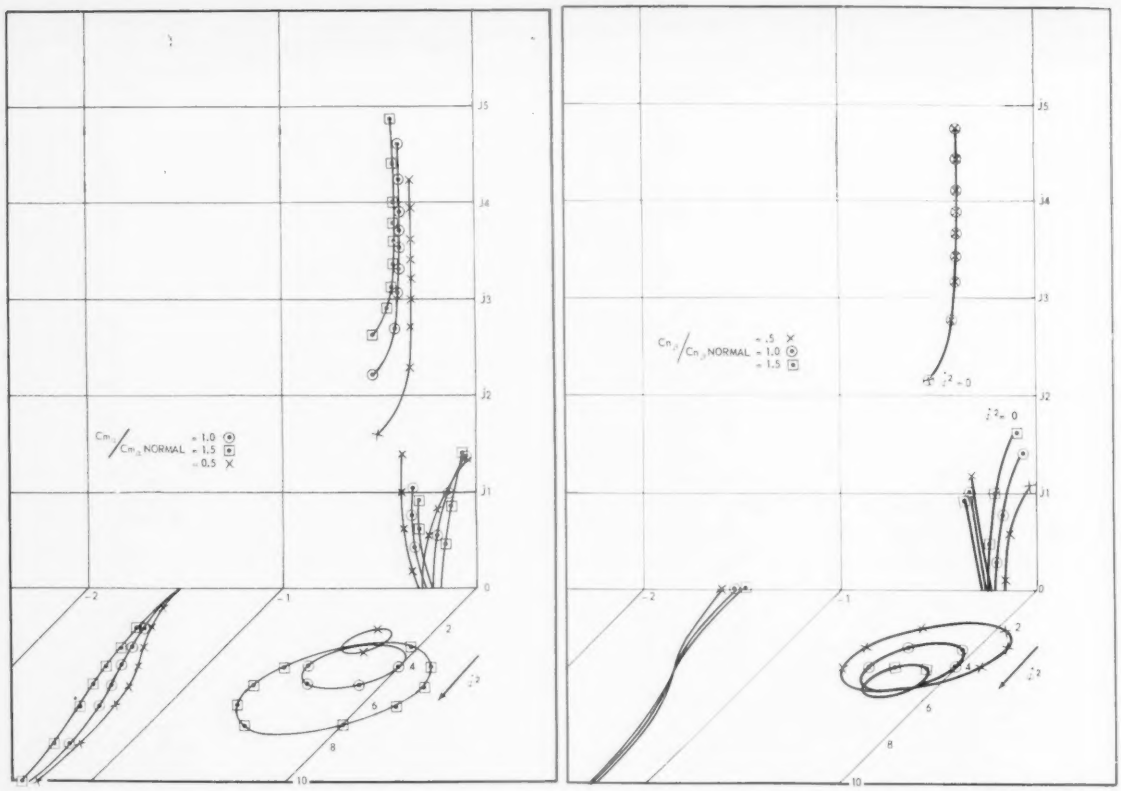

FIG. 2 (*left*). Plot showing how roots of stability equations vary as functions of the square of the roll rate for various ratios of Cm_α to normal Cm_α. FIG. 3 (*right*). Plot showing how roots of stability equation vary as functions of the square of the roll rate for various ratios of Cn_β to normal Cn_β.

values used in this study, this means that, to improve the stability in roll, decrease the effective Cm_α or increase the effective Cn_β.

Improved Stability by Use of Automatic Controls

There are numerous instances where airplanes are too far along in the design stage to be completely redesigned in order to reduce the susceptibility to inertia coupling. The more drastic condition also exists if the possibility of roll coupling is discovered while the airplane is being tested. The question is now raised, what type of automatic control must be used to stabilize the airplane using control surfaces of δe and δr? The assumptions which must be made here are:

(1) δe and δr may be considered separately, and, if one function will help, then both will help more.

(2) The s^0 terms of the determinant are predominant in determining the airplane stability.

(3) δe and δr are incremental values about the trim values.

The determinant of the predominant s^0 terms and the δ_e functions is:

$$\begin{vmatrix} -Z_\alpha & -1 & \dot{\phi}_o \\ -M_\alpha & -M_{\dot{\alpha}} & 0 \\ -\dot{\phi}_o & 0 & -Y_\beta \\ 0 & 0 & -L_\beta \\ 0 & \dot{\phi}_o B & -N_\beta \end{vmatrix}$$

where $A = (I_x - I_z)/I_y$ and $B = (I_y - I_z)/I_z$.

It was determined, by use of an analog computer, that the airplane steady-state maneuvers at the time of initiating the rolling maneuver have little effect upon the ability of the airplane to become roll unstable. Therefore, it was possible to assume the values of α_o, β_o, $\dot{\psi}_o$, and $\dot{\theta}_o$ equal to zero by noting that the zero values are the solution to the steady-state equation for an airplane starting its rolling maneuver at a zero g initial load factor. The factors I_{xz}/I_x, I_{xz}/I_y, and N_p, were removed by virtue of their having less than 1/2 per cent effect upon the stability determinant.

$$\begin{vmatrix} 0 & 0 \\ 0 & \dot{\phi}_o A \\ 0 & 1 \\ -L_p & -L_r \\ 0 & -N_r \end{vmatrix} = \begin{vmatrix} -Z_{\delta e}\delta e \\ -M_{\delta e}\delta e \\ -Y_{\delta r}\delta r \\ -L_{\delta r}\delta r \\ -N_{\delta r}\delta r \end{vmatrix}$$

Now the substitution is made that G_x is the δe function of the variable x. In other words, let $\delta e = G_x X$. When X is α, the stability determinant expands to

$$(-Z_\alpha - G_\alpha Z_{\delta e}) Y_\beta M_q N_r + (-Z_\alpha - G_\alpha Z_{\delta e}) M_q N_\beta +$$
$$Y_\beta N_r (M_\alpha + G_\alpha M_{\delta e}) + (M_\alpha + G_\alpha + M_{\delta e}) N_\beta +$$
$$\dot{\phi}_o^4 AB - \dot{\phi}_o^2 [N_\beta A + (-Z_\alpha - G_\alpha Z_{\delta e}) Y_\beta AB +$$
$$M_q N_r + (M_\alpha + G_\alpha M_{\delta e}) B]$$

which equals approximately

$$M_\alpha N_\beta - \dot{\phi}_o^2 [N_\beta A + M_\alpha B] + \dot{\phi}_o^4 AB +$$
$$G_\alpha [M_{\delta e} N_\beta - \dot{\phi}_o^2 M_{\delta e} B]$$

It should be noted that the factor L_ρ has been removed from this expansion because it enters every term. However, because L_ρ has a negative sign, the airplane will be stable when the sum of the terms is negative and unstable when the sum is positive.

To increase the airplane stability using α feedback to elevator will then be considered impractical because the factor $M_{\delta e} N_\beta$ and $-M_{\delta e} E$ have opposite signs, consequently no value can be chosen for G_α which will increase the stability of the airplane for all roll rates by making the terms $M_\alpha N_\beta$, $-[N_\beta A + M_\alpha B]$, and AB more negative—i.e., more stable. Another point of view is that, with opposite signs for the coefficients of the G_α terms, there is no value (or function) of G_α which will not make one of the terms less stable as another term is made more stable.

Using δe as a function of $\dot{\theta}$ gives the expansion:

$$M_\alpha N_\beta - \dot{\phi}_o^2 [N_\beta A + M_\alpha B] + \dot{\phi}_o^4 AB +$$
$$G_{\dot{\theta}} [(-Z_\alpha M_{\delta e} N_\beta + M_\alpha Z_{\delta e} N_\beta) +$$
$$\dot{\phi}_o^2 (-N_\beta Z_{\delta e} A - N_r M_{\delta e})]$$

If a value of $G_{\dot{\theta}} = K_{\dot{\theta}} \dot{\phi}_o^2$ is chosen, then a considerable improvement should result in the roll stability. This is because the coefficients of the $G_{\dot{\theta}}$ term are negative, consequently any value of $K_{\dot{\theta}}$ will tend to increase the stability of the airplane by making the coefficients of the expansion of the stability determinant more negative.

For $G_{\dot{\phi}}$ the expansion gives approximately

$$L_\rho M_\alpha N_\beta - \dot{\phi}_o^2 L_\rho [N_\beta A + M_\alpha B] +$$
$$\dot{\phi}_o^4 L_\rho AB + G_{\dot{\phi}} \dot{\phi}_o [L_\beta M_{\delta e} N_r - L_r N_\beta M_{\delta e} +$$
$$Z_\alpha L_\beta M_{\delta e} B - M_\alpha B L_\beta Z_{\delta e}]$$

Using $G_{\dot{\phi}} = K_{\dot{\phi}} \dot{\phi}_o$ is about the only possible value, and the advantage of this is doubtful.

For $G_{\dot{\psi}}$ the expansion gives approximately

$$M_\alpha N_\beta - \dot{\phi}_o^2 [N_\beta A + M_\alpha B] + \dot{\phi}_o^4 AB$$
$$-G_{\dot{\psi}} [\dot{\phi}_o (-N_\beta M_{\delta e} + M_q N_\beta Z_{\delta e} - M_\alpha B Y_\beta Z_{\delta e}) +$$
$$\dot{\phi}_o^3 (B M_{\delta e})]$$

The signs of the two terms in $G_{\dot{\psi}}$ are again different so no value of $G_{\dot{\psi}}$ will help all of the terms.

To examine the stabilizing effects of the δr inputs, let H_x be the δr function of the variable x—that is, let $\delta r = H_x X$.

For $H\dot{\theta}$ the expansion gives approximately

$$M_\alpha N_\beta - \dot{\phi}_o^2 [N_\beta A + M_\alpha B] + \dot{\phi}_o^4 AB -$$
$$H_{\dot{\theta}} [\dot{\phi}_o (-M_\alpha N_{\delta r}) + \dot{\phi}_o^3 N_{\delta r} A]$$

For $H_{\dot{\phi}}$ the expansion gives

$$M_\alpha N_\beta L_\rho - \dot{\phi}_o^2 [N_\beta L_\rho A + M_\alpha L_\rho B] +$$
$$L_\rho AB \dot{\phi}_o^4 + H_{\dot{\phi}} [(-M_\alpha L_\beta N_{\delta r} + M_\alpha N_\beta L_r) +$$
$$\dot{\phi}_o^2 (A L_\beta N_{\delta r} - A N_\beta L_{\delta r}) + \dot{\phi}_o^4 AB I_{\delta r}]$$

For $H_{\dot{\psi}}$ the expansion gives

$$M_\alpha N_\beta - \dot{\phi}_o^2 (N_\beta A + M_\alpha B) + AB \dot{\phi}_o^4 -$$
$$H\dot{\psi} [M_\alpha (Y_\beta N_{\delta r} - N_\beta Y_{\delta r}) + \dot{\phi}_o^2 (M_q N_{\delta r} - M_\alpha B Y_{\delta r})]$$

For all of these functions of δr, the signs of the H_x terms are different for the different $\dot{\phi}_o^n$ terms, therefore no δr stabilizing function using $\dot{\phi}$, $\dot{\theta}$, or $\dot{\psi}$ will give unquestionable improvement over the whole flight range. However, to determine the best δr function to use, the ratios between the $\dot{\phi}_o^n$ terms of the H_x functions were compared, and the one with the greatest ratio between terms was considered to have the best possibility of augmenting the stability. This method determined the best rudder feedback to be $\delta r = K_{\dot{\theta}} \dot{\phi}_o \dot{\theta}$.

Conclusion

The results of this study show that, if some form of automatic control is to be used to alleviate the inertia coupling, the best system to use is $\delta e = K\dot{\phi}^2\dot{\theta}$. This feedback should aid the stability at all flight conditions and all rolling rates. This will allow the pilot to make rolling maneuvers which are consistent with the other qualities he obtains from today's high-performance interceptors.

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The critical performance areas—full load take-off ground roll and post take-off rate of climb—are explored, and a comparison of take-off characteristics for a transport aircraft utilizing mechanical flaps, boundary-layer control flaps, or jet flaps is made.

Jet Transport Flap Considerations

W. T. Hamilton
Boeing Airplane Company

In order to achieve the maximum range and payload capability for jet-powered, long-range subsonic aircraft, it is necessary to get the maximum weight into the air from a particular airfield. There are both military and civil take-off requirements, and, in general, they require that flight speeds be attained within a particular distance and that some specified emergency condition climb be available. This paper is concerned with the take-off ground run and the post take-off climb performance for such aircraft. The airplane and flap characteristics presented in this paper are for no particular airplane but are typical for swept-wing, four-engine jet aircraft, such as the Boeing 707.

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The application of any of these high lift devices to a particular airplane configuration has been studied by generating approximate lift-drag polar curves for an airplane utilizing each high lift device. These data result in aerodynamic lift and drag characteristics such as those presented in Figs. 6, 7, and 8. These figures show the ratio of drag-to-lift as a function of lift coefficient, flap deflection, and jet momentum coefficient. The data are presented in this way in order to make the climb angle thrust requirements readily apparent. These characteristics are based on the airplane, out of the ground effect, with the gear retracted, and with the flap deflections indicated. It is believed that this is a reasonable configuration for the emergency one-engine-out climb condition. The best mechanical and boundary-layer control flaps have

Mr. Hamilton is Staff Engineer—Aerodynamics and Power Plants, at the Seattle Division.

GROUND ROLL

$$S_G = \int_0^{V_{TO}} \frac{V\,dV}{\frac{T-D-\mu(W-L)}{W/g}}$$

CLIMB ANGLE

$$\gamma = \frac{T}{W} - \frac{D}{L}$$

FIG. 1. Take-off performance

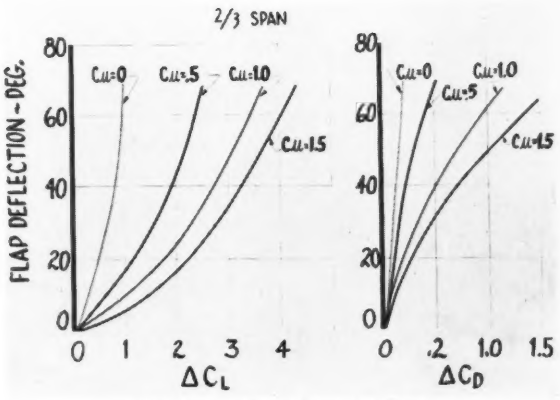

FIG. 4. External flow—jet flaps.

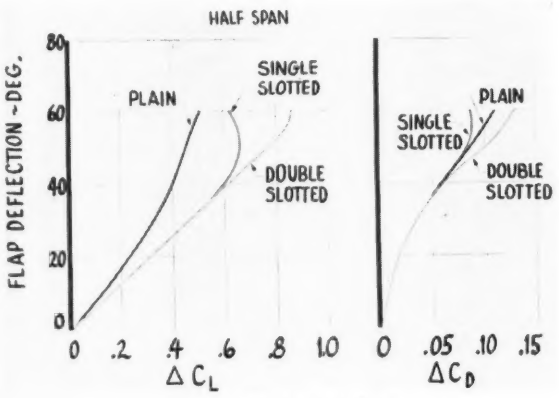

FIG. 2. Mechanical flaps.

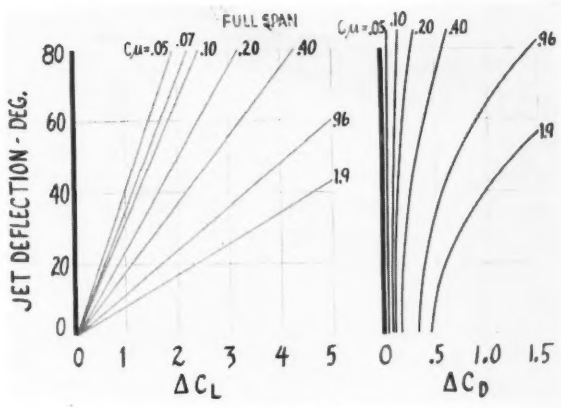

FIG. 5. Jet flap.

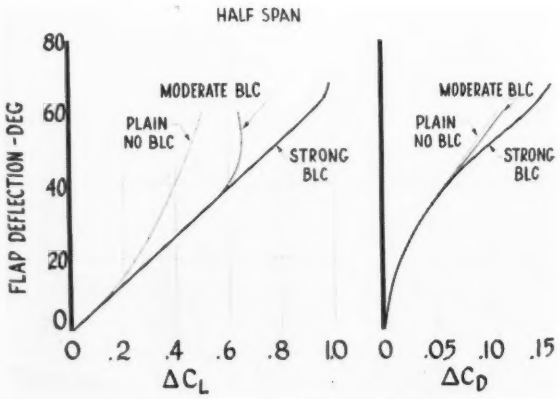

FIG. 3. Boundary-layer control flaps.

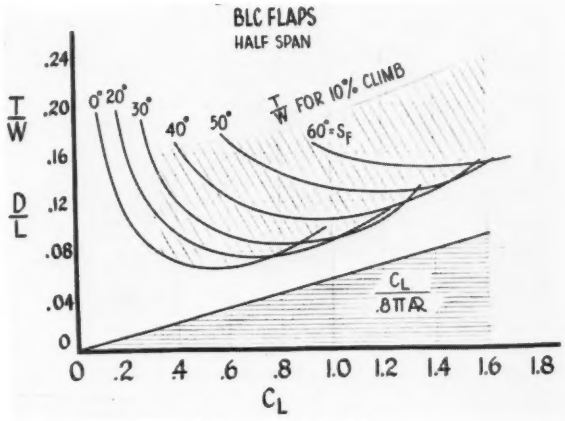

FIG. 6. D/L vs. C_L.

The critical performance areas—full load take-off ground roll and post take-off rate of climb—are explored, and a comparison of take-off characteristics for a transport aircraft utilizing mechanical flaps, boundary-layer control flaps, or jet flaps is made.

Jet Transport Flap Considerations

W. T. Hamilton
Boeing Airplane Company

In order to achieve the maximum range and payload capability for jet-powered, long-range subsonic aircraft, it is necessary to get the maximum weight into the air from a particular airfield. There are both military and civil take-off requirements, and, in general, they require that flight speeds be attained within a particular distance and that some specified emergency condition climb be available. This paper is concerned with the take-off ground run and the post take-off climb performance for such aircraft. The airplane and flap characteristics presented in this paper are for no particular airplane but are typical for swept-wing, four-engine jet aircraft, such as the Boeing 707.

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FLAP DEFLECTION - DEG.

GROUND ROLL

$$S_G = \int_0^{V_{TO}} \frac{V\,dV}{\frac{T-D-\mu(W-L)}{W/g}}$$

CLIMB ANGLE

$$\gamma = \frac{T}{W} - \frac{D}{L}$$

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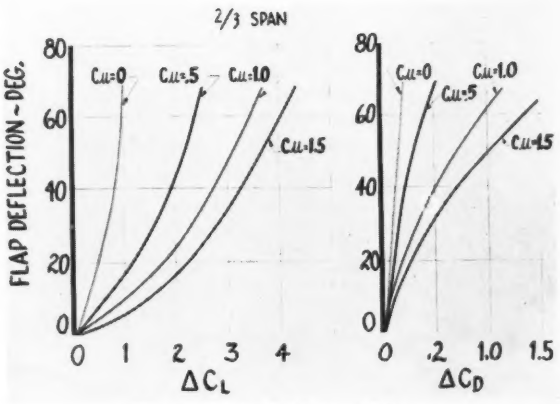

FIG. 4. External flow—jet flaps.

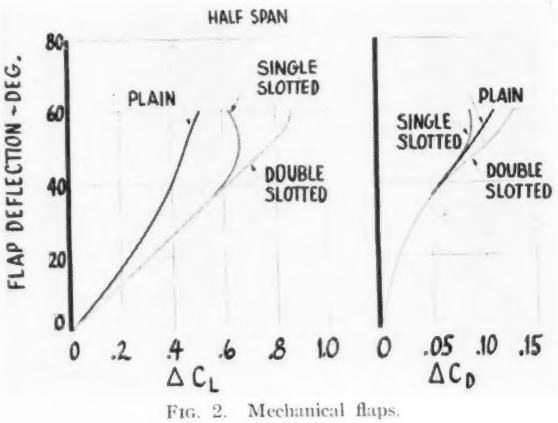

FIG. 2. Mechanical flaps.

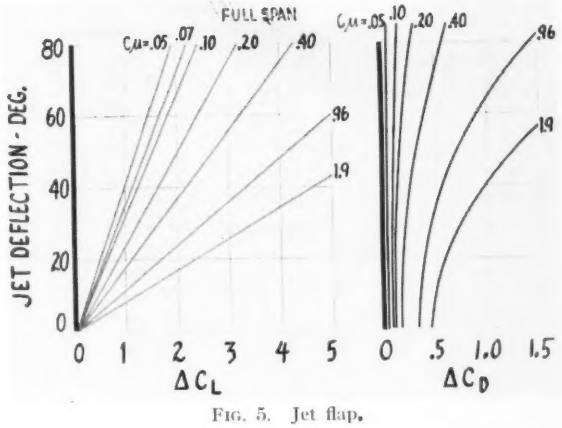

FIG. 5. Jet flap.

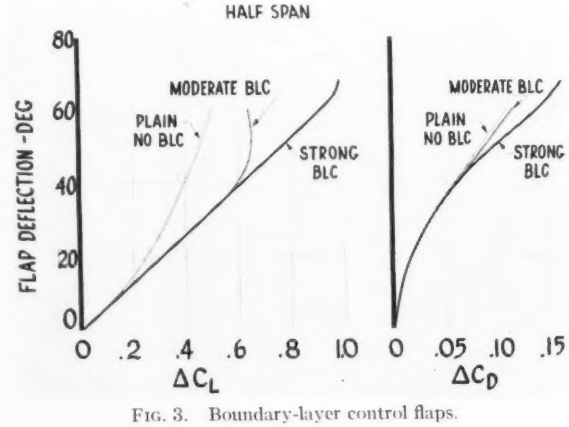

FIG. 3. Boundary-layer control flaps.

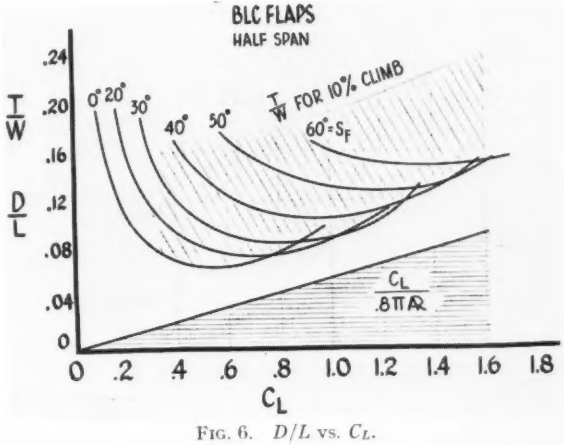

FIG. 6. D/L vs. C_L.

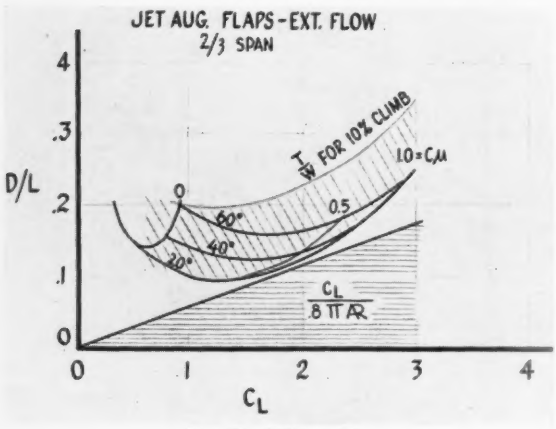

FIG. 7. D/L vs. C_L.

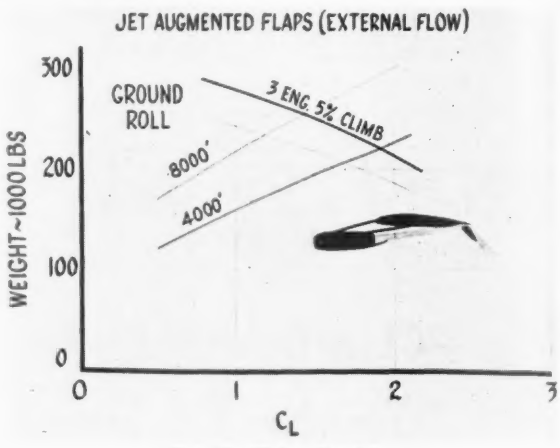

FIG. 10. Take-off weight.

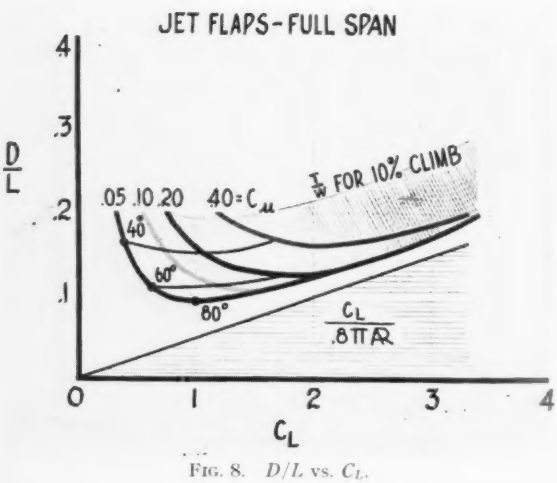

FIG. 8. D/L vs. C_L.

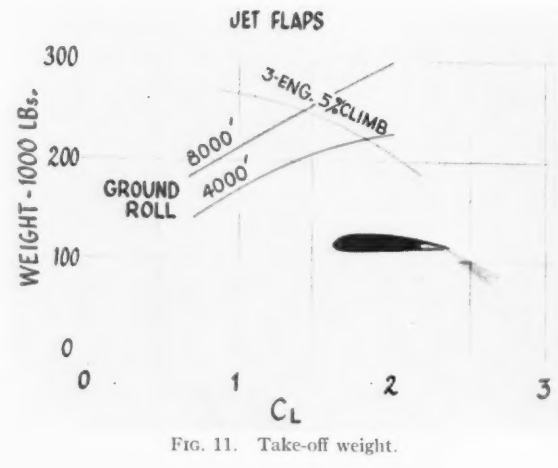

FIG. 11. Take-off weight.

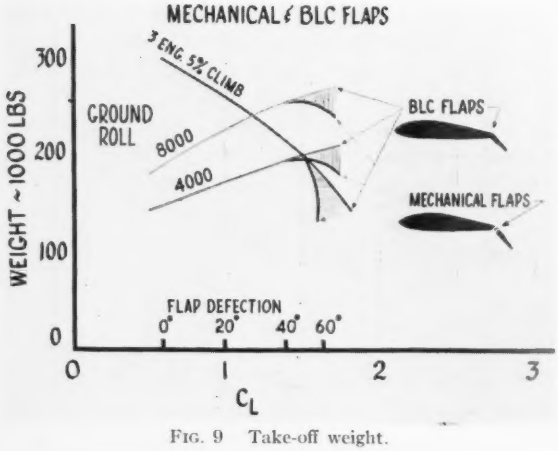

FIG. 9 Take-off weight.

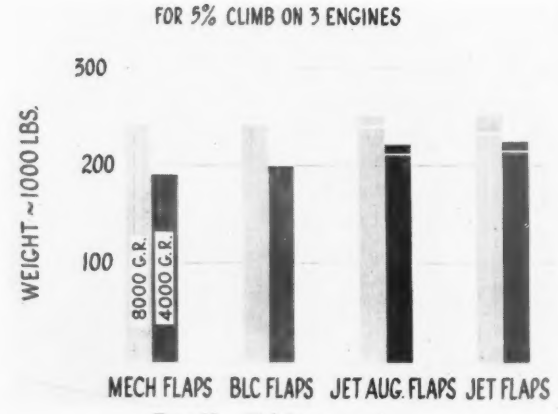

FIG. 12. Weight comparison.

essentially identical lift and drag characteristics up to flap deflections in the order of 50° or 55°. For greater flap deflections, the mechanical flaps stall, and additional lift is not added while the boundary-layer control flaps continue to add lift and drag with additional deflection. These figures show that the drag-to-lift ratio increases as the flight lift coefficient increases, even though we continually increase the flap deflection so as to have the minimum value of drag-to-lift ratio. The family of curves in Figs. 6 through 8 are bounded by envelope curves which represent the minimum drag-to-lift ratios possible for the particular airplane configuration. The upper side of the shaded areas represent the thrust-to-weight ratio that is required in order to have a maximum climb slope of 10 per cent ($5^3/_4$ deg.). It is obvious that, as the flight lift coefficient increases, the thrust must be increased for a given weight and climb slope. On each of these figures is shown $C_L/0.8\ \pi A R$, the asymptote for D/L at high lift coefficients if drag due to lift is $C_L^2/0.8\ \pi A R$. The drag due to lift, as a partial span flap, is varied in angle, is always greater than that of the basic wing. The aerodynamic characteristics of a flapped wing are a function of relative flap span and the amount the air is turned. It is noteworthy that the unseparated flap effectiveness is not appreciably affected by the means of preventing separation (sucking, blowing, or slots).

From an operating economy standpoint, the best flap system is the one which allows the greatest weight to be flown from a particular field. Figs. 9, 10, and 11 present the take-off weight as a function of take-off lift coefficient for both 8,000- and 4,000-ft. ground rolls. These figures also present the take-off weight for a three-engine, 5 per cent climb slope (3 deg.). The basic airplane assumed for these figures had 2,400 sq. ft. of wing area and was powered by four 12,500 lbs. thrust engines. This combination of wing area and sea-level jet thrust was picked to allow a good match for the altitude cruise condition. Fig. 9 shows that both mechanical and boundary-layer control flaps allow the same take-off weight for an 8,000-ft. ground roll and a 5 per cent one-engine-out climb slope. In the case of the 4,000-ft. ground roll, boundary-layer control flaps show a slight advantage over the mechanical flaps if no cost in terms of thrust and weight is charged to the boundary-layer control airplane. Had it been economical to add more engines or larger engines, the boundary-layer control flap would have shown more advantage. The flap angles corresponding to the take-off lift coefficients are shown on the abscissa. It is noteworthy that, for the high weights, the climb and 8,000-ft. ground roll requirements utilize a flap deflection of about 30°, whereas the lighter weight, shorter ground roll case utilizes a flap deflection of about 50°. Figs. 10 and 11 present the same information for the two types of jet flap studied here. These figures were generated with the assumption of no thrust loss due to flattening of the jet or to complicated ducting to prevent control problems should one engine be lost and with it the resulting jet lift on one part of the wing. The light line below the 5 per cent slope climb boundary represents the location of that boundary if the basic engines were reduced in thrust by 10 per cent to allow for such ducting.

The allowable airplane take-off weights for these different high lift devices are compared in the bar charts in Fig. 12. It is noteworthy that for the high weight take-offs long fields are required and that, for the 8,000-ft. ground roll case, essentially no differences in allowable weight exist for the four systems considered, especially if some thrust loss is assumed for the ducting of the jet flaps. For the shorter take-off runs, the jet flap data presented show an advantage in weight off the ground. However, it must be pointed out that no consideration has been given to trimming out the moments resulting from the full span jet flaps and that the ducting of the hot gases from the engines through the wing and out of the trailing edge will certainly result in weight increases and in space problems because of the fuel that must be displaced from inside the wing.

In summary, it appears that subsonic, long-range aircraft having jet-engine sizes matched for maximum cruise efficiency can gain little or nothing from the more exotic high lift devices for the high weight operations which require long runways. Boundary-layer control and jet flaps may offer some advantages for shorter field length operations where larger thrust-to-weight ratios are required.

NATIONAL NAVAL AVIATION MEETING PROCEEDINGS

The *Proceedings* of the Naval meeting (held in San Diego, Calif., August 5–10, 1957) contains all *unclassified* papers presented at the meeting and is now available.

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Francis E. O'Meara
The Institute for Defense Analyses

. . . the application of science and scientific methods to military planning and operations.

Military Operations Research

OPERATIONS RESEARCH is an activity pursued in many different areas these days and in some cases differs very little from management analysis or similar conventional occupations. It is therefore proposed to discuss only military operations research since it was in this context that operations research first became an independent activity.

Perhaps the most outstanding characteristic of operations research is the difficulty its practitioners have in defining it. This has been commented on many times, with the commentator usually proposing his own definition. What seems to be the common trouble with these definitions is that they are directed toward defining a science while operations research has stubbornly remained an engineering occupation. In the simplest sense, a science is a body of systematized knowledge as opposed to engineering which is the application of science to human needs. It therefore would seem quite sensible to limit the definition of military operations research to the simple statement that it is the application of science and scientific methods to military planning and operations.

In the old days (World War II, that is), military operations research was almost exclusively concerned with improving the operational effectiveness of what we now call weapon systems. The methods and results of such work have been well described by Morse and Kimball, but, with the end of the war and cessation of operations, there was a drastic decline in the amount of work that could be undertaken by these established methods. The controlled experiment or measure of effectiveness had suddenly become most elusive.

Military operations research did not fold its tent and fade away, but it did clearly undergo a change. Some people felt that it should prepare itself for a new conflict and in the interim establish better procedures and techniques on the basis of past experience. This was not really a very popular approach, but it must be admitted that it probably paid off more than any other track during the Korean War. Others felt that valuable work could be done within the conventional form using war games and training exercises as sources of experimental data. Still others felt that with the sudden advent of such new weapons as jet aircraft and nuclear weapons they could best serve in the capacity of scientific advisers and liaison experts. While it is not proposed to criticize any of these approaches, few operations analysts will deny that there have been pitfalls.

Those who might have paid excessive attention to how things were done during World War II soon discovered that they were in the same class with the legendary military mind that is intent on fighting the last war over again. Even in Korea much World War II experience had to be junked or re-evaluated because of the peculiar circumstances of this conflict. Those who have substituted war games and training exercises for operational data have been beset with difficulties. Training operations are seldom conducted with any semblance of reality, if only because of the expense involved. War games are fascinating paper exercises, but one does not have to be terribly sophisticated to realize that little more comes out of a war game than is put into it. Finally, those who have gravitated toward the area of scientific advisers ultimately discover that they have departed from military operations research by any definition.

It is interesting to consider military operations research as a subject for its own analysis. Thus we might ask: What is the purpose of an operations research office in terms of an end product? What are the essential elements of such an office? How do we measure the effectiveness of its operation? How can we control and improve its effectiveness?

The opinions expressed here are those of the author and not those of the Institute for Defense Analyses.

To change the order of things a bit, the essential elements of a military operations research office are an organization of predominately civilian scientists and the placement of this office in a major staff position with a reasonably direct access to the military commander. Viewed as a separate civilian staff, we may then ask what purpose it fulfills that military staffs do not. Characteristically, this civilian scientific staff is habituated toward solving problems by scientific method. That is, it attempts to observe the common and repeating features of phenomena, to form a hypothesis relating these observed phenomena, to verify this hypothesis by controlled experiments or observations, and to predict other phenomena arising from this verified hypothesis. It is this skill in scientific method which is most valuable in a scientific staff as distinct from a military staff. The second notable characteristic is the freedom and independence of thought that a civilian staff may and should have.

How do we measure the effectiveness of a military operations research organization? There is a simple rule here which applies to all staffs—namely, has its work made the decision-making job of the commander easier? In the particular case of the operations research staff, its most notable contributions will be in two distinct areas. One is the analysis and evaluation of operations and operating concepts involving weapons systems with a view toward optimizing the efficient employment of these systems in the military organization. The emphasis here is on the methods for efficiently employing these systems as distinct from the hardware specifications analysis which the producing contractor is obviously far more capable of doing. The second important area is the analysis of future weapons systems with a view toward guiding their development and integration into operating military forces. This is an area calling for a considerable degree of imagination and judgment since it is not only a question of adapting weapon systems to military organization and missions, but perhaps, more importantly, it involves the inverse problem of adapting organizations and missions to new weapons systems.

How can we control and improve the effectiveness of an operations research organization? Here the answer lies in selection of personnel and proper internal organization. There is no magic or inviolable type of internal organization, in fact, there is much to be said for a policy of minimum organization. But there must be at least enough organization to convey the "engineering" idea that the final product should have some utility to the military commander. Knowledge for its own sake is not a fundamental aim of military operations research.

The director of an operations research office should be a civilian scientist himself, as should be most of his staff. The reason for this is apt to be quite clear to a civilian but not at all so to a military man. This requirement is by no means a reflection on the intelligence or integrity of a possible military director. How could it be, since the whole purpose of the operations research office is to serve the military commander. Rather, it stems from the essentially pragmatic reason for setting up such an organization in the first place. If there are certain areas in which a civilian scientific staff can contribute to a military organization, then it is basically because they are civilian in organization and management as well as in composition. If the initial premise is not true, then there should not even be such an organization.

It is perhaps a rather trite observation that an organization can only be as good as the people in it. In military operations research, however, there is not only the problem of finding qualified people but also the more basic problem of trying to decide what kind of people to look for. Because people with a great variety of backgrounds have done well in operations research, the simplifying assumption is often made that almost anyone can do well at it. Sad to say, this has not proved a very practical means of selecting people. There was once a musician who became a quite competent physicist, but this really does not imply that physicists should be recruited from the musicians union.

If the essential character of a scientific staff is its skill in using the scientific method, then the most logical place to look for recruits is among the sciences where the scientific method is at a premium—that is, in the "hard" sciences such as physics, mathematics, and chemistry. This is not to say that valuable people will not be found in such areas as sociology, history, or psychology, but the criterion should be skill in scientific method rather than specific educational background.

One difficulty with scientists in operations research is their predilection toward viewing knowledge as an end in itself. This commonly takes the form of considering a written project study or report as the final product, whereas, from the engineering point of view, the commander's decision is the final product, and there is often a considerable gap between the report and the decision.

Prior experience is as important in operations research as in any other activity, and even the finest scientific training does not necessarily assure that a man will become a good operations analyst. Obviously, the first people who started operations research were without specific prior experience, but there has been a considerable amount of water under the bridge since then, and experience has taught some tricks of the trade. Moreover, it must be remembered that military operations research is a civilian activity in a military organization, and it is desirable that the individual analysts have some experience and familiarity with military people and military organizations, either through prior military service or working experience with operational military commands. This is not an indispensable requirement, but it certainly helps to have some knowledge of how the customer operates.

Within the military services there have been two different approaches toward the organization of operations research offices. The Army and Navy have

established centralized offices, ORO and OEG respectively. The Air Force has adopted a more diversified approach with the primary emphasis on autonomous command offices. There is a centralized office in USAF Headquarters as well as the RAND Corporation which has in part somewhat similar functions, but the majority of Air Force operations analysts are located in independent offices attached to the major commands. Each of these offices has evolved its own method of operating, and each probably feels that its own methods are superior. Of course, much depends upon the particular mission of the parent organization and the ability of the military commander to recognize the advantages and limitations of a civilian scientific staff.

An example of how a particular operations research office has evolved is the office at SAC Headquarters. Starting with nine people in 1946, it has grown to approximately 35 at the present time. Organizationally, it has shifted from the Directorate of Plans to the Directorate of Operations and finally to a special staff position directly under the Command Section. In 1954 the distinction between a scientific advisory function and the operations research function was formalized by the establishment of a separate Chief Scientist Office.

There are two aspects of the SAC operations research office which are of particular interest. One is the absence of any assigned military personnel with the exception of some clerks and an executive officer. It might appear that this is a mistake since the addition of some military people to an operations research office usually contributes considerably in establishing realistic operational factors. However, it has been found that the close contact between the military staff and the civilian operations analysts possible at SAC Headquarters can accomplish the same results without the occasional embarrassment that occurs when a military operations analyst has to deal with another staff officer of higher rank.

The other notable aspect of the SAC operations research office is the absence of written project reports. Since the end product of any operations research office is the direct service it gives to the commander and his staff, the communication of project results is best accomplished by means of a briefing or oral presentation. This policy thus faces up to the fact that a written report is seldom an ideal means of communication and at the same time avoids the pitfall of regarding a written report as an end in itself.

Returning to military operations research in general, there are a multitude of different organizational structures that can probably be adapted to this field. But there are a few guiding principles that are indispensable to any such organization. First, the personnel must be skilled in scientific method; second, the organization must be imbued with the idea that there is a distinct service that a civilian scientific staff can render to a military commander; third, the military commander must have confidence and understanding in what his operations research staff can and cannot do. If these requirements are met, much can be expected from military operations research.

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Ray D. Kelly, United Air Lines, Inc.

Along with technical considerations, public opinion, "psychological readiness," and the economy into which the airplane will be projected are of great concern.

Air-Line Technical Requirements Planning

United Air Lines' management demonstrated its anticipation of the place of the turbine engine in air-line operations as early as 12 years ago. Our Engineering Development Section was instructed to begin an evaluation of turbine-engine potentials in 1945. We began making visits to engine manufacturers and different research centers in early 1946. Some contacts were made with the military and it was recognized then that the adaptation of the turbine engine to civil operations represented a very major step from the standpoint of equipment and proper application.

One of the first turbine engines proposed as having commercial possibilities was the General Electric TG-100 turboprop. In May and June of 1946 visits were made to the Martin Company and then, in company with Martin engineers, we went to Schenectady, N.Y., to visit the General Electric Plant to study the possibilities of the installation of the TG-100 turboprop engine in a United Air Lines' Martin 304 airplane. The possibility of such an installation was rejected after it became apparent that hot day and high-altitude performance of this turboprop suffered so much that we would not have any safe "one engine out" operation in this airplane with such a power plant. This was the first time that it had been brought home to us that the turbine engine suffers more power loss on a hot day than does the reciprocating engine.

The first formal report of the Engineering Development Section concerning turbine engines is dated October, 1946. This study covered the different types of potential turbine power plants and defined those areas in which each of them seemed to have the best commercial possibilities. It is significant that in this report the turboprop, the turbojet, and the turbofan were all listed as having good potentialities. At that time it was believed that the turboprop would be the first power plant to be applied to air-line operation. Theoretically, it was efficient at moderate speeds and it seemed to promise much better fuel economy than the jet engine. The following is quoted from that report:

"Whenever airplane cruising speeds at 450–700 m.p.h. at altitudes of 30,000–45,000 ft. become economically feasible in transport operation, turbojet engines will come into general use. A considerable amount of engineering development and study will have to be made, however, before this era will arrive."

It was recognized that the turbine fuels would be considerably different from aviation gasolines. Because of the lack of a high octane requirement they should be less costly and less volatile. Such a fuel would also represent certain improvements in safety, particularly from the standpoint of ground handling.

At that time the development of the turbine engine was just getting under way for military applications. The state of the art for both materials and design criteria was far from being advanced. The following were listed as major problems:

1. The development of turbine materials to operate at high temperature under high stress.
2. The development of combustion chambers to effectively burn the fuel cleanly and to stand up under high temperatures over long periods of time.
3. The development of adequate control systems to regulate the fuel flow, prevent overheating and excessive speed, and achieve optimum efficiency and economy.

In looking back over these 12 years, it is significant that materials development and the design criteria have improved immeasurably. These advancements have been achieved primarily under military sponsorship. Component efficiencies have now progressed to the point where they represent an acceptable commercial economic capability.

The first commercial jet transport proposal was made to us in February, 1947. Interestingly enough it boasted a cruising speed of 540 m.p.h. at 30,000 ft. which is right in line with current thinking. However, it was a smaller airplane having a take-off gross of 145,000 lbs. and carrying only 40 passengers and baggage plus 5,000 lbs. of cargo. It required eight engines because at that time the maximum thrust ratings for jet engines were only on the order of 5,000 lbs. each. It had an operating range of about 2,000

The author is Superintendent of Technical Development.

miles. Our studies of this airplane first demonstrated to us the high proportionate fuel costs for turbine-powered aircraft.

In February, 1947, we visited major engine manufacturers, Pratt & Whitney, Wright Aeronautical, and Allison. We found a considerable difference in opinion as to whether the turboprop or the turbojet would first be available for use by the air lines. The turboprop represented a more logical first application for civil transports, but even in 1947 it was apparent that the military was going to place primary emphasis on the turbojet engine. This made it difficult for us to encourage any of the engine manufacturers to develop the turboprop for commercial applications.

All during this time we were reading and hearing about the work which the British were doing. They believed that their wartime turbine power-plant experience properly qualified them to produce the first civil turbine-powered transports. There was no possibility for them to compete with American reciprocating-engine-powered transports which were already in use throughout the world. Some eight or nine projects sponsored by the British Government and relating to the application of turboprop and turbojet engines to commercial aircraft were undertaken. Of these, only the Viscount and the Comet came into actual service.

In February, 1950, J. A. Herlihy, Vice-President, Engineering and Maintenance, accompanied by the writer and another member of his staff, made a trip to Europe for the purpose of studying European progress. During this trip, flights were made in the prototypes of the Vickers Viscount and the de Havilland Comet 1.

These flights were adequate to demonstrate to us the great future potentials of the turbine engine. We were particularly pleased with the low cabin noise level and freedom from vibration. We could not help but be elated with the higher speeds achieved with jet aircraft.

The early contributions made by the British in the field of turbine-powered civil aircraft have been very important for the whole industry, and they are due much credit for having had the courage to undertake the pioneering work needed to demonstrate the effectiveness of the turbine power plants, both turboprop and turbojet, in transport aircraft.

After the European trip, United Air Lines began to make operational and economic studies of a number of proposed aircraft. American, British, and Canadian designs were studied objectively. Comparisons were made against our DC-6 airplanes. This exercise soon demonstrated that the jet transport could be expected to provide a greatly superior service which, for purpose of differentiation in United Air Lines, became designated as "Blue Ribbon" service, and the jet transport was referred to as the Blue Ribbon Transport. The turboprop airplane showed good possibilities, too, but rather in the area of replacement for current piston-powered aircraft.

However, these same studies indicated that the Blue Ribbon Jet, to be economically feasible, must be fast, operate at high altitudes, and have fairly long-range capabilities. These limitations immediately made it obvious that the jet transport must be considerably larger than existing piston transports in order to carry sufficient payload to justify its use.

Thus, in 1952, United Air Lines' Technical Development Division began writing "Requirements for a Jet-Transport Aircraft." Transcontinental nonstop range capabilities against winter winds with full payload was the initial criterion.

A great many conferences were held with the aircraft and engine manufacturers. The overall problem as to proper aircraft size and performance was discussed with the engineers of other major air lines.

No one had any very solid data on the operation of jet transports and little was known about the wind and weather conditions at the altitudes at which these flights would be made. The British were reporting reasonably satisfactory operations with their Comets but we felt that this did not provide an adequate basis for our studies.

In 1952 it was decided to run a simulated day-in-day-out "Paper Jet" operation over United's system. A hypothetical airplane was designed conforming to United Air Lines' requirements. The first simulated operation was started in June, 1952. The jet transport characteristics were as follows:

Average Cruising Speed	545 m.p.h. at 30,000–40,000 ft.
Payload	22,500 lbs.
Take-off Weight	200,000 lbs.
Landing Weight	140,000 lbs.
Fuel Capacity	13,000 gals.

Upper air data analysis was a most important aspect of this operation. A United Air Lines' research meteorologist devoted his entire time to this program. It got under way in earnest in the latter part of 1952. Eventually, two transcontinental flights each way each day were operated. With the aid and cooperation of Dispatch personnel at San Francisco, Chicago, and New York, the daily operations were carried out as though the air line were actually flying the two round trips per day. One trip each way each day made a stop at Chicago, and the other flew nonstop. This paper jet exercise continued for something over a year. Some 608 flights were logged, and it brought out the following conclusions:

1. The schedule reliability of jet transports should be as good or better minute-wise than that of current aircraft. For the nonstop westbound trips, the fastest trip was 45 min. early and the slowest 20 min. late. Eastbound the fastest trip was 35 min. early and the slowest 25 min. late. This was based on an 85 per cent on-time schedule.

2. The ability of the jet flight crews to take advantage of current weather knowledge is actually improved in a jet airplane because the higher speed permits them to go further in a given length of time and

to plan flights more accurately because of the shorter time interval between point of departure and destination. It was apparent that the so-called jet streams can be used to advantage at times.

3. There was no particular difficulty with respect to planning for fuel reserves. It is true that every phase of fuel control must be precisely handled with a jet transport in order not to reduce payload or affect safety of operation. By carefully planning each day's flight on the basis of available knowledge of weather conditions, headwinds, temperatures, traffic, available payload, and the like, there should be no difficulty with our actual jet operations.

4. The current meteorological information which is available at the 30,000–40,000 ft. levels, while not as comprehensive as that at lower levels, was nevertheless considered adequate for the initial planning and operating of jet transports.

United's management had indicated that there could be little serious interest in jet aircraft unless and until safety and economy, consistent with the levels of current reciprocating-engine-powered aircraft, could be reasonably expected. The extensive prior military operation of turbine engines of the types likely to be used for civil transports was the best assurance of power-plant integrity. The engines used in bomber airframes were at least an approximation of the transport configuration.

But could a jet transport produce a ton-mile or a seat-mile as cheaply as the piston-engine-powered airplane? By what prodigious stretch of the imagination could a jet engine, burning 1 lb. of fuel or more per lb. of thrust per hour, compete with a piston engine requiring less than 1/2 lb. of fuel per horsepower per hour? The ability of the turbine to burn a somewhat less expensive fuel was at best a minor compensating factor.

To increase our concern further, the manufacturers let it be known that a transcontinental jet transport would likely cost four to five millions of dollars or more. To United Air Lines' management this appeared an impossible figure.

The paper jet exercise had demonstrated that to carry an adequate payload transcontinentally nonstop, a much larger airplane than the DC-6 was mandatory. Further, our performance calculations had shown that the most efficient propulsive effort with the direct jet comes at speeds just below the significant rise in the drag curve. A reasonable average to use in calculations was taken as 550 m.p.h. average cruising.

It began to be apparent that the product of the number of seats per jet airplane times the average block speed times the number of flight hours of utilization expected per year resulted in an amazing number or revenue seat-miles per year. Thus, it was readily demonstrated that one jet transport represented the transportation capability of some 15 DC-3 airplanes or about 3.5 DC-6's.

But there was the question as to whether jet transport could effectively be used over United Air Lines' system for as many hours per day or year as could the equipment then in service. Another study made in 1954 related to the "Scheduleability of Jet Transport Aircraft." This study was an application of the jet to the major segments of the United Air Lines' System with allowances for servicing and equipment turnarounds. Desirable departure and arrival times were maintained. The conclusions were that the greater speed of the jet worked out very well on our system, indicating at least as good hourly utilization as with airplanes then in service. The faster jet permitted a better utilization of the daylight hours because of the decreased time en route. This was an unanticipated advantage for both operator and passenger.

Up until this time the primary initiative and responsibility for this program had been centered in the office of the Vice-President, Engineering and Maintenance. But now every administration and division of the company became vitally interested in the potentialities and problems of jet transport operations. Once the technical advantages had been demonstrated and the economics seemed reasonable, the integration of this new concept of airplane into the thinking and planning of the air-line organization began to take place. It goes without saying that the aircraft builders had a very big part in spreading the good news. Their operating cost estimates were more optimistic than ours, and it now became important that some of their enthusiasm be tempered with realism.

It then became the duty of the Engineering Division specialists to examine minutely every facet of the manufacturers' proposals. Indeed these engineers, each in their respective fields of structures, power plants, controls, electrical equipment, instruments, hydraulics, passenger service equipment, flight performance, airport limitations, etc., often collaborated with the manufacturers' project engineers early enough so that the detailed designs and selection of equipment were significantly influenced by air-line knowledge of day-in-day-out operating requirements.

Of greatest importance in planning the successful integration of new aircraft into the air-line system is the potential market which can be anticipated for the period of introduction and during the effective life of the new equipment. The responsibility for this falls primarily on the Economic Controls Administration. Their studies largely determine the number of units required and best routing applications. All such recommendations must be coordinated and modified to anticipate the needs of the Sales and Traffic Administrations.

But it is of no benefit to plan without the assurance of adequate funds. The Finance and Property Administration becomes intimately involved in the early serious planning. They accept and bear a very major responsibility in the entire picture.

The new equipment must be operated and flown by the Transportation Services and the Flight Operations Administrations. Specifications and requirements must be closely coordinated and cleared with them. Every

TABLE 1
Comparative Airplane Data

	1929 Boeing 80-A	1959 Douglas DC-8
Price	$ 85,000	$ 5,000,000
Maximum Takeoff Weight #.	17,500	250,000
Airplane Weight Empty #.	-	124,160
Wing Span, Ft.	80	139'-9"
Wing Area, Sq.Ft.	1,220	2,759
Overall Length, Ft.	56'-6"	150'-2"
Overall Height, Ft.	-	42'-4"
Fuselage Width, In.	63½	144
Cabin Pressure Differential #.	0	8½
Fuel Capacity, Gal.	500	17,600
Passenger Seats (First Class)	18	122
Cargo Capacity, #.	900	14,150
Space Payload.	4,057	34,260
Nonstop Range, Mi.	450	Transcontinental
Average Cruise Speed, MPH.	120	561
Landing Speed, MPH.	55	140
Takeoff Distance, Ft.	-	9,440
Cruising Altitudes, Thousands of Ft.	1 to 10	25 to 40
Wing Loading, #/Sq.Ft.	14.3	90.7
Power, Sea Level Takeoff	3 ea. P&W Hornet Eng.@ 525 HP ea.	4 ea. P&W JT-3 Jets @ 10,000 # Thrust
Crew.	3	5-6
Utilization, Avg. Flight Hrs. Per Day.	4.75	9.0
Available Seat-Miles Per Year - Million.	3.15	200.00
Ratio of Transportation Capability.	1	63.5
Elapsed Time New York-San Francisco.	31:00	5:55
" " San Francisco-New York.	28:00	4:55
Number of Enroute Stops.	14	0
One-Way Fare (First Class)	$ 227.50	$ 158.85 / Tax
" " " (Coach).		$ 99.00 / Tax

other administration and department is likewise involved to a greater or lesser degree.

In the final decision, the President, his General Staff, and the Board of Directors must have become convinced of the reasonableness and need for new equipment such as the Jet Transport Airplane. It is a major decision for the company, its stockholders, and its employees.

In a serious long-range development and finalization of an advanced transport-aircraft program, the engineer fortunate enough to have been in on it from the first has an appreciation for the great number of variables which go into the equation of air transportation progress. Most of these are indeterminate variables and change day to day, week to week, and year to year. Depending upon how he thinks and reacts, as well as what he knows, an individual's answer to problems of future aircraft applications, costs, performance, and even safety cannot help but be biased. The results of his calculations, even by rather exact formulas, can be optimistic or pessimistic depending upon small but consistent shifts in the values used in the equation. This can be illustrated by a simple example. Suppose that six factors are involved in an equation, and one individual consistently underrates the true value of each factor to 95 per cent and another person is slightly more optimistic and just as consistently uses a value of 105 per cent. The sixth power of 0.95 is approximately 0.735 as compared to 1.34 for the sixth power of 1.05. Thus, in this illustration, the final result can vary almost two times between individuals whose difference in judgment might be considered relatively insignificant in their analysis of any of the individual factors.

But the problem is not as easy of analysis as this because there is no way of assigning mathematical values or even defining many of the significant forces which affect the "time and tide" of aeronautical progress. These may be political, economic, and catastrophic events, human inertia, public acceptance, or rejection. Timing, based on psychological readiness, is all-important too. We simply recognize these factors as "intangibles" and must then depend upon and accept the judgment and/or intuition of those having the responsibility of decision.

The engineer assigned the task of planning for the future must recognize and acknowledge the certain influence of these intangibles. He must know that even those factors of his equation which can be assigned definite values today will have different values for and during the period for which he is planning.

This represents a frustrating experience for the engineer. His training has always emphasized analysis and accuracy based on known or measurable quantities. His textbooks always developed exact answers. When asked to solve a problem involving futures, he is expected to give a precise solution. As an engineer, he is not likely to admit that, at best, his answer will only be a first approximation. But certainly this is the case, and the exercise will need to be redone, almost before the first approximation is completed, because of changes already operating in so short a period of time.

After a while the development engineer realizes progress is not possible without this constant change. His calculations will not define a plateau but rather a stepping stone, useful for the moment in providing a surer pathway to the future.

This repetition of efforts and constant realignment of sights can become a frustrating experience until one learns of the necessity for it. Sometimes the repetition is done only because it is of assistance in the communication of an important idea or relationship to others, who can now use it as a helpful stepping stone.

By occassionally looking backward, one is better able to contemplate the potentialities of the future. It is not meant to imply that by reviewing the past one can calculate the exact form and detail of the future. Rather, he will thereby recognize how much more quantitative progress has been achieved today than could have been computed, based on the state of the art, at some significantly earlier date.

For example, let us go back to 1929 when the Boeing Model 80-A trimotored airplanes were first introduced on Boeing Air Transport System between Oakland and Chicago. They were the first airplanes on which stewardesses were to be employed in the following year, reflecting the early desire to cater to passenger comfort and convenience. They were contemporary with the Ford and Fokker trimotored airplanes. These new transports, to many people, represented a definite plateau of service, probably an ultimate. No one dared or could have proposed or imagined the jet transports of 1959 destined to be operating 30 years later. They could not then have visualized the pressurized Boeings, DC-6's, and Constellations achieved in less than 20 years, or even the DC-3 coming in some 7 short years.

To illustrate further the span of progress achieved, it may be well to compare the physical and performance

characteristics of the Boeing 80-A and Douglas domestic DC-8. See Table 1.

It is a startling revelation that one DC-8 has the same passenger transportation capacity as 63.5 Boeing 80-A's. It is also significant that at $85,000 each, 63.5 Boeing 80-A's would have cost 5.4 million dollars in 1929 currency.

To develop the same air lift as one DC-8 jet transport, the equivalent 63.5 Boeing 80-A trimotored transports would be generating 62,000 hp. (at 325 hp. per engine in cruising flight). It is confusing to compare the "thrust" of jet engines with "horsepower" of reciprocating engines, but a rough equivalent horsepower for the DC-8 cruising at 30,000 ft. would be 29,000, or less than half.

From the standpoint of fuel consumption, a similar comparison reveals that the $63\frac{1}{2}$ 80-A's would have consumed 6,700 gal. of gasoline per hour as contrasted to the one DC-8's cruising fuel consumption of 1,900 gal. per hour at 30,000 ft.

All of these comparisons reveal the amazing and generally unpredictable engineering advancements which will have been made from 1929 up to and slightly beyond the present time. The jet airplane is a machine tool having an enormous capacity to produce our products of passenger-miles or ton-miles. It is obvious that the 80-A and the jet do not produce equivalent products. The value or quality of the jet product from the standpoint of timesaving and comfort is far greater than the best which the 80-A could produce. On the other hand, the jet cannot be expected to operate economically in the short-haul market to which the 80-A was limited.

The author believes that this example of air transport progress achievement during the past 30 years is a significant indication of the accelerating tempo which is technically possible during the next 30 years. Yet our engineers are no more capable today of visualizing the exact state of the art in 1989 than it was possible in 1929 to write a set of Jet Transport Requirements for equipment to be flown in 1959.

Surely, intangibles and indeterminate variables will plague and frustrate the engineers of the new era the same as in the past. So very much will depend upon the public knowledge and appreciation of the benefits of still further advances in transportation. There must be an enthusiasm for it and a recognition that all such progress is expensive and requires great effort and imagination. The engineers will plan, calculate, and recalculate, just as they have in the past, to develop the stepping stones of progress.

Sherman M. Fairchild Publication Fund Papers

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IAS News *(Continued from page 21)*

• **Amphenol Electronics Corporation** has announced what it calls a new concept of lateral acting mating in oblong connectors with 15 butt-type contacts in which interconnecting equipment is fastened via a sliding action.

• **Arma, a Division of American Bosch Arma Corporation** has begun a modernization program at its Garden City, N.Y., plant, the firm says, to provide the most advanced electronic assembly manufacturing facility in the east.

• **Avien, Inc.,** has announced the appointment of Seymour Rabinowitz as Engineering Manager. Mr. Rabinowitz had been Supervising Engineer, Atomic Engineering Branch, Chief of Product Engineering, Picatinny Arsenal, Dover, N.J.

• **Beech Aircraft Corporation** has announced delivery of six Beechcraft H35 Bonanzas to Central American Airways Flying Service, Inc., for use in U.S. Army instrument flight training.

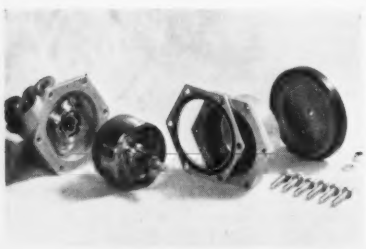
• **Bendix Aviation Corporation** has bought stock interest in Poroloy Equipment, Inc., Van Nuys, Calif., from the National-Standard Company. Poroloy is the trade name for a porous stainless steel used where high temperatures are involved. Charles C. Tillinghast, Jr., has joined the firm as a Director, member of the Administration Committee, and Vice-President in charge of foreign investments and plants, . . . Scintilla Division has announced a new high-frequency ignition system for the largest aircraft piston engines said to provide faster sparking action and to give greater resistance to spark plug fouling and erosion. . . . Radio Division has developed a dual automatic direction-finding unit, labeled the DFA-70, for Air France Caravelle aircraft. The division also has developed what it calls the first reusable container to be used by an aviation electronics manufacturer in regular production shipping . . . J. Allan MacLean has been appointed Assistant Group Executive of the corporation and will be in charge of the Products Division.

• **Boeing Airplane Company** reports a study to determine the effects of radiation on transistors in the Bomarc missile has been under way for several months. Tests have been conducted near atomic pile sites at Arco, Idaho, and Los Alamos, N.M. . . .Transport Division specialists carrying out a study of domestic air-line traffic predict it will increase four and one-half times between 1955 and 1965. The firm has announced open commitments from Boeing to thousands of other firms totaled $6.5 million for the first 6 months of 1957. Varig Airlines of Brazil have ordered three Boeing 707 jet aircraft, the firm announced.

Convair's F-102A is shown releasing a salvo of 24, 2.75-in. folding-fin rockets during test firing at Holloman AFB. A coat of gray enamel resists corrosion from the rocket blast whose fiery exhaust is only momentary.

• **Cornell Aeronautical Laboratory, Inc.,** held a symposium on complex instrumentation necessary for high-speed flight in September, which was sponsored by the Navy's Bureau of Aeronautics. Called an Air-Data Symposium, the meeting was classified and covered current problems, techniques, requirements, and hardware developments. Nineteen technical papers were delivered.

• **Douglas Aircraft Company, Inc.,** has announced that captive firings of the Thor IRBM missile have been scheduled near Sacramento, Calif. The firings will take place at a new joint Douglas-Air Force test site. . . .El Segundo Division reports Navy pilots have flown specially instrumented A4D-1 aircraft at the Nevada atomic bomb test site to determine blast and thermal responses of the plane to nuclear explosions. Division engineers have developed a portable electric bomb hoist said to weigh only 47 lbs. and to lift up to 2,500 lbs. at 15 ft. per min. with accurate loading up to 13 ft. with 1/32 of an inch. The firm's General Offices have announced plans to build a new commercial jet training and publications center at a 39-acre Santa Monica Division site in Los Angeles County.



Bendix Aviation Corporation Products Division has announced a new, nonelectric antiskid device (shown in the exploded view) said to prevent aircraft wheels from locking and sliding when brakes are applied. The firm reports the unit is installed on each braked wheel and operates independently, cycling only when the wheel it controls decelerates because of wheel slippage.

• **The Dow Chemical Company** has announced the promotion of Robert Pittsley from magnesium salesman to magnesium sales supervisor, Detroit territory.

• **Eastern Air Lines, Inc.,** has inaugurated daily nonstop flights between New York and Mexico City using DC-7B aircraft with first-class configuration.

• **The Garrett Corporation** has opened an office in Geneva, Switzerland, and moved its New York City office to new quarters at its Aero Engineering Division building, 220 Old Country Road, Mineola, N.Y. . . . AiResearch Manufacturing Division of Arizona has announced a new air motor said to operate at 1,000°F. with no conventional lubrication or cooling. The division also is flight testing an F-101B inside a giant altitude chamber simulating 50,000 ft. and under extreme high and low temperatures. The division's new pneumatic controls building was formally opened. . . .The AiResearch Aviation Service Division has moved its sheet metal fabrication department out of its former location providing 16,000 ft. of additional hangar space at its Los Angeles International Airport facility.

• **General Dynamics Corporation** has announced a merger with The Liquid Carbonic Corporation which has become the Liquid Carbonic Division of the parent firm. . . .Convair Division (San Diego) has scheduled cold weather tests at Mt. Washington, N.H., for the 880's CJ-805-3 jet engines. SAC Commander Gen. Thomas S. Power has made a familiarization flight in the B-58 at Fort Worth. Five military air bases in the Texas-Oklahoma-New Mexico area have been designated as alternate B-58 landing fields. Dudley H. Digges has been appointed Special Assistant—Convair 880 Jet Transport Project at San Diego. Robert E. Honer has been named Chief Electronics Engineer of the division. The San Diego parts sales department, formerly under the contracts office, has been transferred to operations. Sixteen Air Force specialists took part in a human engineering study of ICBM missile

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And remember, Fluoroflex-T hose assemblies are now available with either reusable or permanently attached fittings.

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Resistoflex

CORPORATION

Roseland, New Jersey • Western Plant: Burbank, Calif. • Southwestern Plant: Dallas, Tex.

Lockheed Aircraft Corporation's JetStar utility transport is designed to carry 10 passengers 1,700 miles at 500 m.p.h., according to the firm. Statistics: 58 ft. long, 53-ft. wing span, two Bristol Orpheus engines providing 10,000 lbs. thrust, and a 500 m.p.h. cruising speed at 40,000 ft. The wing is swept 34 degrees along the leading edge and has a 523-sq.ft. area. This prototype is aimed at the military market, Lockheed says, but also will be available for commercial users if a demand develops. A four-engine version also is scheduled.

propellant handling conducted at March AFB by Convair-Astronautics engineers. . . .Stromberg-Carlson Division has announced promotion of the following executives in the Electronics Division: Douglas W. Anderson, now Assistant to the Vice-President; P. R. Sultzbach, now Production Manager; and William F. Hafstrom, now Manager, Marketing-Industrial Products.

• **General Electric Company,** Aircraft Gas Turbine Division, Small Aircraft Engine Department has established a T64 Project for the design and development of an aircraft gas turbine in the 2,600-hp. class for the Navy. The department is using what it calls the nation's first automatically programed resistance welding machine to weld tabs on cylindrical liners for jet engines. The Jet Engine Department placed on display in Chicago, Ill., the firm's CJ-805 jet engine, the commercial version of the J79 military engine that will power the Convair 880. John H. Baker has been named department Manager of Marketing. Jack S. Parker (AF), Vice-President and General Manager of the division, has been named Vice-President, Public and Employee Relations for the Company. John B. Montgomery has been appointed Division General Manager. . . . Defense Electronics Division, Light Military Electronic Equipment Department has announced a new lightweight, integrating rate gyro with a newly developed self-contained temperature control said to operate on the heat-of-fusion principle and to maintain a temperature of 80°C. with a tolerance of 1/3 degree. . . . Apparatus Sales Division has published Bulletin GEN-169, Thymotrol Adjustable Speed Drive Selector, a slide-rule-type plastic device for selecting the proper motor, control panel, and operator's station of general-purpose Thymotrol adjustable speed drive. The Instrument Department has announced what it calls the first lightweight, low-price compass system with an electrically driven, panel-mounted gyroscope for business aircraft.

• **General Precision Equipment Corporation,** General Precision Laboratory Incorporated has published a catalog on its new Model PD-500 Closed-Circuit Television Camera obtainable from the firm at 63 Bedford Road, Pleasantville, N.Y. . . . Kearfott Company, Inc., has announced availability of an all-electronic chopper said to contain no moving parts and to have a minimum operating life of 5,000 hours. The firm also named five men to new positions: Frank J. Delves to Director of Sales; Eugene T. Ferraro to Director of Service; Winton S. Smith to General Sales Manager; Joseph O'Brien to General Service Manager; and Charles H. Wheately to Manager, Advanced Planning

• **G. M. Giannini & Co., Inc.,** has announced two new products—a temperature probe conforming to MIL-P-25726, designated Model 49147, said to utilize a resistive sensing element to measure accurately stagnation temperature over the range of −70°C. to +350°C. and at speeds to Mach 1.5; and a split-wedge transducer for angle-of-attack measurements to Mach 3, conforming to MIL-T-25627 (USAF), designated Model 2562, said to provide accurate angle-of-attack information at all speeds and altitudes throughout a wide operational range.

• **The B. F. Goodrich Aviation Products, a Division of The B. F. Goodrich Company,** has purchased land and buildings formerly owned by West Coast Loading Company at Rialto, Calif., for use in rocket propellants research. Murray C. Bartlett has been named Manager of Product Engineering.

• **The Goodyear Tire & Rubber Company** Aviation Products Division has developed a foot-thumping warning device (a skid-warning system) which is said to sense an impending skid and warn the pilot by rapping the bottom of his foot with a plunger.

• **Grumman Aircraft Engineering Corporation** has appointed three distributors to handle marketing of the firm's commercial transport "Gulfstream." They are Atlantic Aviation Service, Inc., Philadelphia, Pa.; Pacific Airmotive Corp., Burbank Calif.; and Remmert-Werner Corporation, St. Louis, Mo. The plane will sell for $700,000—with electronic, radio, and other interior equipment to be installed by the distributors, Grumman announced.

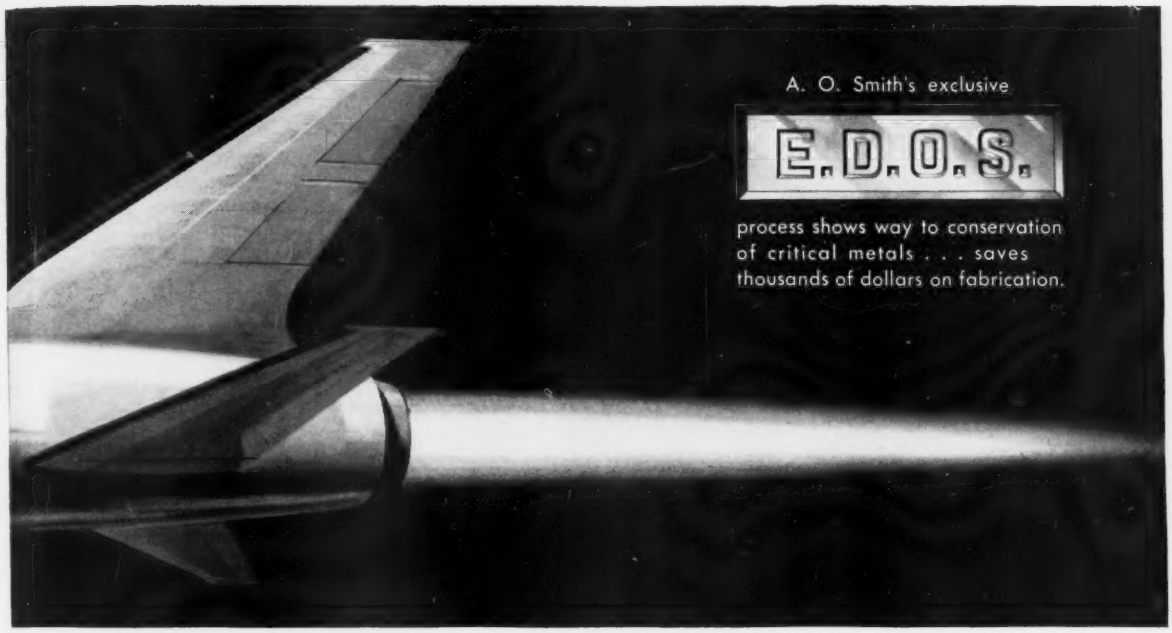
• **Kelsey-Hayes Company** has announced the Heintz Manufacturing Company of Philadelphia, Pa., will be operated as one of its divisions, by agreement of both firms.

• **Walter Kidde & Company, Inc.,** is performing a radiological survey of soil, water, air, and biological conditions in the vicinity of Industrial Reactor Laboratories Test Reactor being built by AMF Atomics near Plainsboro, N.J. The survey is being made by Kidde Nuclear Laboratories.

• **Lear, Incorporated** reports that work on its advanced instrument panel for the Air Force is in its second stage. The Lear "Whole Panel" development program is part of the Wright Air Development Center broad cockpit improvement program. The firm also announced that it is supplying the air inlet control for Republic's F-105 Thunderchief. . . .LearCal Division engineers have developed a gyro drift recorder Model 2249, said to detect, indicate, and record with extreme accuracy the minute increments of drift in high-precision gyros. . . . Lear-Romec Division has developed a portable submersible axial flow bilge pump, designed to permit passage through a 4-in. diameter hole and said to pump sea water at temperatures ranging from −10°F. to +130°F. at a rate of 85 g.p.m. at a 20-ft. head of water (8.65 psi).

• **C. W. Lemmerman, Inc.,** has granted manufacturing rights to its new lightweight portable jet-engine sound suppressor to Air Logistics Corporation of Pasadena.

• **Lockheed Aircraft Corporation,** Missile Systems Division is investigating the use of nuclear power to propel missiles with the help of a new three million volt Van de Graaff positive ion accelerator. Research will cover nuclear structure, reactor design, radiation shielding design, and material damage. The 40-ft. tall X-17 rocket is on a nationwide Air Force tour said to be the first ballistic vehicle exhibited across the country. Division scientists report they have achieved high-velocity shock waves which reached speeds of more than 100,000 m.p.h. along a specially designed, advanced hydromagnetic shock tube. The research is providing data on the flow of highly ionized gases at extreme Mach Numbers and temperatures. Rolf K. M. Landshoff, division Consulting Scientist, has compiled in one volume the research work of eleven United States and British physicists and astronomers in the field of Magnetohydrodynamics—combining the sciences of fluid flow and electromagnetics. . . .Georgia Division reports completion of in-flight refueling tests with the C-130 at Patuxent River, Md. Two of the Hercules transports have been delivered to the 317th Troop Carrier Wing in France. Division sales is being reorganized to place greater emphasis on Jetstar and C-130 commercial business, with W. G. Myers


A. O. Smith's exclusive
E.D.O.S.
process shows way to conservation of critical metals . . . saves thousands of dollars on fabrication.

A-286 alloy ring for a finger of flame

Today, products are becoming increasingly complicated and costly. Further, there's mounting pressure to put them into production in the shortest possible time.

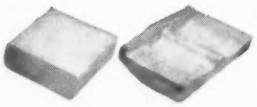
That's where E.D.O.S. (Engineered Designs for Optimum Structures) may fit into your picture — speed-wise, cost-wise.

This A. O. Smith process consists of precision forging and contour rolling followed by flash or fusion welding. With it, even the most difficult-to-work metals can be shaped . . . quickly fabricated into the parts you need with only minimum finish machining (in most cases). There's no wasted metal, no need for expensive successive machining operations to "whittle" a part down to size. Parts cost savings of up to 70% have been reported.

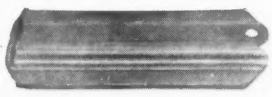
A. O. Smith's 9,000-ton, single-action, precision-forging press is the only one of its size in the country. And their 1,800-ton contour rolling mill is also the only one of its type and size in the country.

Since World War II, E.D.O.S. has helped make A. O. Smith a major supplier to the aviation, rocket, missile and related industries. A. O. Smith products are currently helping to accelerate the VANGUARD project.

E. D. O. S. applied to a jet engine case



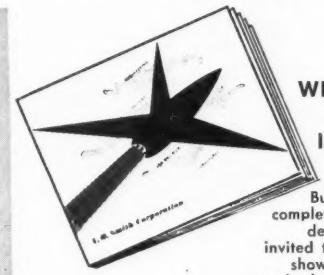
The process begins with 4 high nickel alloy blanks—saving over 50% in costly material over conventional processes.



The second step involves pre-forging and an initial roll to form a piece of this configuration.

Then, the pre-forged and rolled blanks are formed into quadrants.

. . . and the 4 quadrants are flash-welded to form the finished part. Relatively small machining job still needed is done by the customer.



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CORPORATION

AERONAUTICAL DIVISION

Milwaukee 1, Wisconsin

A. O. Smith International S. A., Milwaukee 1, Wis., U. S. A.

FIGHT VIBRATION WITH VIBRATION

New twist in testing ...a torsional exciter

TORSIONAL testing *has* been done with rectilinear motion shakers by applying ingenuity in linking table to specimen. But here's a new MB exciter that produces torque *directly*. Its performance characteristics permit you to use it as a *calibrator* for torsional pickups and accelerometers . . . as well as for testing gyros and relays (as examples), or checking torsional vibrations of armatures, or determining torsional modes in various rotating parts.

OPERATING FACTS

At free-table, no load, this MB Model CA 1050 Exciter oscillates at up to 1600 cps without resonance in moving elements. It develops 110 ft. lbs torque, which produces angular accelerations as high as 1570 radians/sec/sec. Maximum total displacement is 45°.

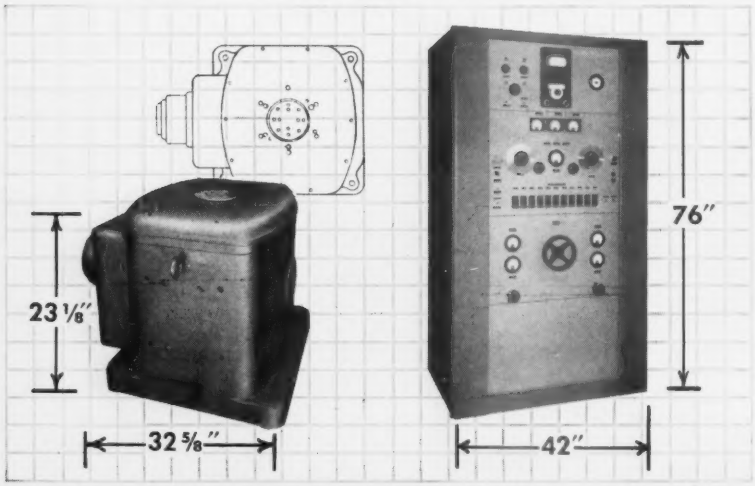
A MATCHED SYSTEM

Any one of several MB electronic power supplies drives the equipment, depending on the specific frequency range, power, and performance you want. The MB Model T51 Power Supply shown comes with automatic cycling controls if desired.

SEND FOR DETAILS

Technical data available. And for more information on how and where to use this unusual equipment, contact our staff of vibration specialists. You can't come to a better qualified authority on the subject . . . nor to one more willing to help on your specific vibration testing problems.

MB *manufacturing company*
A DIVISION OF TEXTRON INC.
1073 State Street, New Haven 11, Conn.
HEADQUARTERS FOR PRODUCTS TO ISOLATE . . . EXCITE . . . AND MEASURE VIBRATION



named Sales Director and R. I. Mitchell promoted to Sales Manager. A 90-ton testing machine for applying tension or compression loads up to 600 tons for evaluation of C-130 structural parts has been installed by the division. Paul K. Senter has been named Chief Master Scheduler and Alvan L. Hall, B-47 Chief Project Coordinator. The firm reports Ansett/Australian National Airways has purchased four Electras, and Pacific Southwest Airlines, three Electras.

• **The Martin Company** has presented what it calls the first completely integrated missile system to an Air Force Developmental Engineering Inspection team of 100 members at Baltimore. The TM-76 Matador system contains the missile, its launcher, a prime mover, test equipment, and ground handling equipment.

• **Minneapolis-Honeywell Regulator Company** has named Richard A. Brown Manager, Service Engineering, at the firm's new inertial guidance plant in St. Petersburg, Fla.

• **Norden-Ketay Corporation** has announced the move of its Precision Components Division and Gyromechanisms Division into new quarters at Commack and Huntington Station, N.Y. Two new bulletins issued by the firm describe a BCT-300 transistor curve tracer and Florida Gear Division capabilities and facilities. Copies are available from Norden-Ketay at Commerce Road, Stamford, Conn. A new test set for flight-line testing aircraft pressure instruments and systems has been developed by the firm. The set is said to simulate two types of temperature probes and generates selected pilot and static pressures facilitating flight-line checking of several instruments.

• **North American Aviation, Inc.,** Autonetics Division has announced successful functional and environmental tests of its electromechanical components for guidance and control systems at altitudes of 90,000 ft.

• **Northrop Aircraft, Inc.,** has created a new division called Nortronics for handling the firm's activity in the design, development, and manufacture of electronic, electromechanical, and optomechanical products and components. The firm also announced that it has developed a new type of captive fastener for use on electronic subassemblies and given the manufacturing rights to the Moran Company of El Segundo, Calif.

• **Nuclear Development Corporation of America** has designed what it calls a new and significant contribution to nuclear engineering, an Electrolytic Analogue Computer, to supply researchers with essential information about heat conditions in the interior of nuclear reactors. Designed for Pratt & Whitney Aircraft, United Aircraft Corporation, the computer is said to set up an analogous situation in which measurements of electric current and voltage in an electrolytic liquid are comparable to conditions of heat flow and temperature in corresponding locations of a reactor.

• **Pacific Scientific Aeroproducts** has completed a new plant in Anaheim, Calif., and reports it is now producing such aircraft components as cable tension regula-

The Boeing KC-135 Jet Stratotanker designed for aerial refueling of SAC's bombers and fighters

Flyweight Jockey for a High-flying Boom...

The Boeing KC-135 jet tanker is the USAF's first production plane capable of in-flight refueling of supersonic bombers and fighters at jet speeds and altitudes.

To maneuver the mighty tanker's refueling boom with pin-point accuracy, Boeing development engineers designed a lightweight, pivoting "Ruddevator"... a 30 x 60 inch honeycomb sandwich control surface.

A critical problem in the design of the uniquely efficient sandwich structure was the selection of a structural adhesive to splice the several sections of internal core as well as to bond the skins to the core. Obviously, the adhesive would have to withstand enormous operational punishment including severe sonic buffeting.

The adhesive selected for this crucial task: Narmtape® 102... formulated specifically with non-brittle elastomeric constituents to provide unmatched fatigue resistance under highest stress and vibration. The KC-135 Ruddevators' more than 200 hours of trouble-free service life are further testimonial to the ability of Narmco adhesives to perform under rugged operational requirements.

Facing a structural bonding problem? Let Narmco's outstanding family of sandwich and metal-to-metal adhesives point the way to an economical, performance-test solution!

NARMCO

PIONEERING THROUGH RESEARCH

Write today for specific performance and fabrication data on NARMCO structural adhesives. Narmco technical field representatives throughout the United States and Canada can assist in solving your structural design problems quickly, efficiently, economically.

NARMCO RESINS & COATINGS CO. DEPT. S-17, 600 VICTORIA STREET, COSTA MESA, CALIFORNIA

LOS ANGELES SEATTLE FORT WORTH DAYTON TULSA PHILADELPHIA TORONTO

Vertol Aircraft Corporation has announced it is flight testing an Army H-21D helicopter powered with two General Electric T-58 turboshaft engines. Production models are powered with a single piston engine. Vertol says the two new engines should increase payload by 40 per cent and speed by 50 per cent.

tors, guidance and control instruments, and its new "SAF-T-MATIC" aircraft restraint system.

• **Pan American World Airways, Inc.,** has announced one of its Stratocruisers has made the first commercial flight to the Antarctic in history, carrying Navy personnel to McMurdo Sound. John B. Gates has been elected Vice-President, Finance. . . .Latin American Division has installed a telephone tie-line between Havana and Miami to facilitate reservations for continuing flights from either point.

• **The Ramo-Wooldridge Corporation,** Computer Systems Division has developed a new transistorized electronic digital control computer for collecting and analyzing experimental data and controlling experimental runs in test facilities such as wind tunnels, structural and engine test stands, and flight tests. Designation is RW-300. It was specifically designed to control a wide variety of manufacturing processes, where process instruments are read automatically by the computer and adjustments made automatically on the basis of calculations, according to the firm. Three new Vice-Presidents elected by the company are Ruben F. Mettler, Associate Director, Guided Missiles Research Division; Burton F. Miller, Director, Communications Division; and Milton E. Mohr, Group Director, Control Systems and Boston Divisions.

• **Reaction Motors, Inc.,** has named J. F. Harrigan Manager, Dayton liaison office, jointly maintained by RMI and Olin Mathieson Chemical Corporation.

• **Republic Aviation Corporation** has installed electronic test equipment said to "look through" steel, aluminum, and titanium to locate internal flaws before the metals are used in aircraft. The unit includes an ultrasonic immersion tank with mechanized search-unit positioning equipment, electronic "flaw detection" equipment, and a bridge crane for material handling. The firm also announced the start of construction of a $1.2 million, 3,000 m.p.h. wind tunnel.

• **Ryan Aeronautical Company** has developed an advanced electronic automatic navigator, Model 108, for Army L-20 aircraft. Ryan says the Doppler-type instrument automatically computes and indicates the course and distance to a preset destination; provides ground speed, drift angle, latitude, and longitude; and automatically computes and indicates wind.

• **Servomechanisms, Inc.,** has developed a new Barometric Altitude Controller said to measure aircraft and missile altitude deviations as small as $2^1/_2$ ft. at sea level and will manufacture the instrument for Hughes Aircraft Company. The firm also has announced availability of a new brochure on the Magnetics Division and a mail order-type catalog on "Mechatronic Development Apparatus." The brochure may be obtained by writing to the Magnetics Division, 1000 West El Segundo Blvd., Hawthorne, Calif.

• **Simmonds Aerccessories, Inc.,** has announced the election of Gerald J. McCaul to Vice-President, Contracts and Service Division; and Myron G. Domsitz to Vice-President, Research and Development Division.

• **Solar Aircraft Company** reports that it is developing a new variable-speed gas-turbine engine for Army flying platforms, an adaptation of the constant-speed YT-62, designed for a one-man helicopter. Military designation is YT-66. The firm also has published a new brochure describing its 500-hp. Jupiter gas turbine. It may be obtained by writing to 2200 Pacific Highway, San Diego 12, Calif.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has developed an air-borne, radar "homing beacon" designated AN/APN-69 which is said to help fuel-hungry aircraft find aerial tankers from hundreds of miles away. The firm also disclosed that it is providing super guidance-radar for the Navy's Talos and Terrier missiles. The missile guidance systems, SPG-49 for Talos and SPQ-5 for Terrier, are said to have antennas resembling gigantic searchlights. Sperry has announced a new type of basic flight reference—a Twin Gyro "table" said to differ in major respects from conventional two and three gyro platforms. The instrument incorporates two identical directional gyros, set at right angles to each other, according to the firm.

• **Stanley Aviation Corporation** has announced that Ogden W. Boden, formerly with North American Aviation, has joined the firm as Vice-President in charge of Engineering. In this capacity, he will be a director of the corporation and will assume active supervision of Stanley's engineering activities in the fields of missile equipment training devices, flight safety equipment, and commercial products. The firm also announced development of a new electronic tool, Mini-Lab, said to represent a novel technique in electronic breadboarding for the rapid development, assembly, study, and testing of circuits and components. It has been designed specifically for subminiature, miniature, and semiconductor circuitry with a grid of tiny jacks arranged in the form of tie points, voltage busses, ground busses, coupling junctions, and input and output terminals.

• **Thiokol Chemical Corporation's** house organ, *Thiokol Facts*, Vol. 4, No. 1, features an article on "Designing Rocket Engines" that is said to combine discussion of theory and practical application. It may be obtained by writing the firm at 780 North Clinton Avenue, Trenton 7, N.J.

• **Trans World Airlines, Inc.,** has inaugurated polar flights from the West Coast to Europe the company announced.

• **Union Carbide Corporation,** National Carbon Company has developed a fuel cell using hydrogen and oxygen to produce electricity. The company reports this direct conversion of the chemical energy of gases into electricity will economically produce thousands of watts of power. First application has been the power source for the Army's "Silent Sentry" field radar set, said to be the smallest known. The company's Research Laboratories report they have produced temperatures above 7,000° F. with an arc image furnace—highly polished curved mirrors concentrate rays from a carbon arc into a small high-energy beam. . . .Linde Company's Jet-Piercing process to disintegrate or spall extremely hard rock that would wear out drills is being used on the St. Lawrence Seaway project, the firm reports.

• **Vickers Incorporated** has announced a new aircraft miniature vane pump cartridge said to deliver 1.04 g.p.m. at 1,000 psi and 10,000 r.p.m. Its output is said to be 0.6 hp. and is less than $1^1/_8$ in. in diameter, weighing 2.5 oz. The firm also announced that a new variable displacement piston-type hydraulic pump reportedly capable of 4,000 psi is in production and is said to permit operation in fluids and engine lubricating oils with particle sizes up to 40 microns.

• **Vitro Corporation of America** has named Lester A. Wells Executive Vice-President of its Thieblot Aircraft Company division. Mr. Wells formerly was President and General Manager of Engineering & Research Corporation of Riverdale, Md., according to Vitro.

Progress with **TITANIUM**

Announcing...

Two new Titanium alloys for high temperature applications

MST 821... *the highest strength weldable sheet & bar alloy in 400—1000°F range*

MST 2.5Al-16V... *the first readily formable, heat treatable sheet alloy*

Two new alloys developed by Mallory-Sharon now extend the high temperature usefulness of titanium.

MST 821 is a weldable sheet and bar material with exceptional high temperature strength. It offers strengths equivalent to similar titanium alloys at temperatures *two hundred degrees* higher, in the 400 to 1000°F range. MST 821 is thermally stable, and has good ductility and formability.

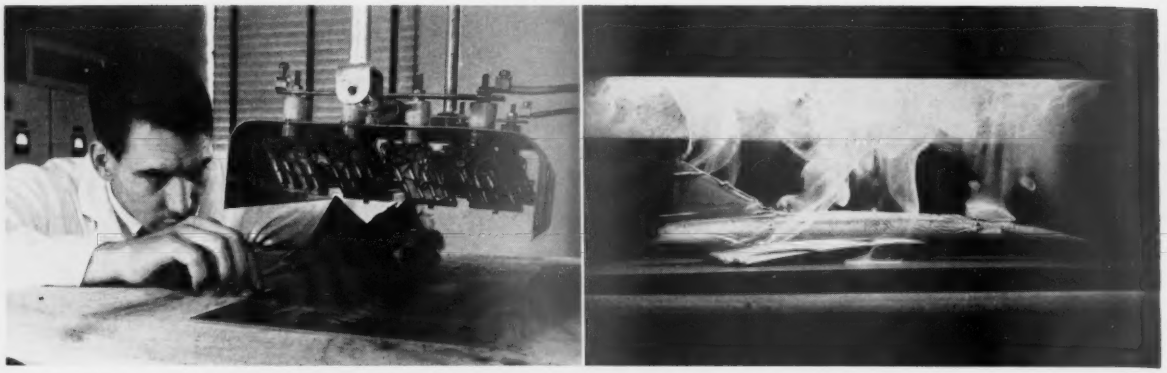
MST 2.5Al-16V was developed in response to needs of the airframe industry for a sheet alloy which would be soft and formable in the annealed condition, and which could be heat treated, after forming, to high strengths while retaining ductility. With this material, yield strength can be as low as 50,000 psi, to permit easy fabrication, then increased to 150,000 psi by heat treatment. Age hardened sheet has good short-time hot strength—about 100,000 psi yield strength up to 800°F.

These alloys, now in limited commercial production, are further evidence of rapid advances in titanium. Use Mallory-Sharon's outstanding technical experience and service on your present requirements — or future plans—in titanium.

MALLORY SHARON

MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets



Westinghouse Electric Corporation's new elevated temperature test facility consists of banks of tubular infrared lamps, three-channel ignitron controller, strip chart temperature recorders, regular control (computer) channels, master control desk, unit substation, and bus duct distribution. Designed to study the effect of high temperature on aircraft structures, the unit can create a simulated "thermal barrier" of 2,500°F. in 12 sec., according to the firm. The melting model, photographed after 4 sec., was used to demonstrate the rapid rate of temperature increase. Westinghouse says in normal use full-scale airframes and components are tested.

• **Westinghouse Electric Corporation** has announced completion of a new wing to its Air Arm Division facility at Baltimore that adds 100,000 sq.ft.—most of it for office space for some of the plant's engineers. The expansion also includes a roof-top laboratory for evaluation of airborne electronic systems. Clifford S. Cody has been appointed senior resident representative for the firm at Rolls-Royce, Limited, main aircraft engine plant in Derby, England.

• **Weston Electrical Instrument Corporation, a Subsidiary of Daystrom, Inc.**, has published a long-scale panel instrument bulletin that may be obtained by writing to the firm at Newark 12, N.J.

IAS SECTIONS

Chicago Section

Chicago Helicopters Carry 7,000 Passengers a Month

"Commercial Helicopter Operations" were discussed by Robert Angstadt, Vice-President, Operations, Chicago Helicopter Airways, before 55 members at the September 18 meeting.

Mr. Angstadt traced the growth of CHA which began flying airmail routes in 1949, serving 50 communities in the Chicago area as Helicopter Air Service, Inc. Passenger service began on November 12, 1956, between Midway Airport and O'Hare International Airport with three Sikorsky S-55 helicopters. In June, three larger S-58's were put into service now linking Midway, O'Hare, and the Loop (Meigs Field).

Traffic has risen to more than 7,000 passengers per month in only 10 months of operation, Mr. Angstadt said. Passengers pay 50 cents per seat-mile between Midway and the Loop, and about 30 cents between Midway and O'Hare and O'Hare and the Loop.

He described the use of autorotation and concluded it is easier to make an autorotation landing than a power-on landing. He said instrument flying will not be needed until the advent of multi-engine helicopters and that stability at present is almost adequate without aids.

He answered questions about maximum payload, economy of the S-58 compared to the S-55, development of commercial compared to military helicopters, utilization, overhaul, icing, blade feathering tracking and flapping, and control upon loss of tail rotor.

After the talk, members visited CHA facilities.

J. S. ISLINGER, *Secretary*

Daingerfield Subsection of the Texas Section

Northrop Scientist Discusses BLC

Eric E. Groth spoke on "Boundary-Layer Control for Drag Reduction" at the September 18 meeting. Dr. Groth is an Engineering Specialist, Northrop Aircraft, Incorporated, Hawthorne, Calif.

In a talk, portions of which were classified, he discussed factors which influence transition, methods of boundary-layer bleed and stabilization, equivalent suction drag, and advantages gained through use of boundary-layer control.

He described subsonic and supersonic applications, considering wind-tunnel and free-flight experimental data.

DORR LOBRECHT, JR., *Secretary*

Hampton Roads Section

NACA Research Work Explained

A Student Night for cooperative and other college employees of NACA Langley

This composite shows high school science groups at NACA Langley Aeronautical Laboratory facilities during a visit sponsored by the Hampton Roads Section Student Activities Committee. Langley staff members gave demonstrations and talks on problems in heating, supersonic speeds, and reduced take-offs and landings.

BOEING 707
starts a new era of Jet Transportation

America's first jet airliner recently streaked across the country in three hours and 48 minutes for a new transcontinental passenger plane record. The plane carried 52 people and made the 2,325 miles from Seattle to Baltimore at an average speed of 612 miles an hour at altitudes of six miles and above.

To control such fast planes at high altitudes requires control cables designed to fit the application. Engineers at American Steel and Wire have cooperated with airplane manufacturers in designing American Tiger Brand Control Cables that meet the most rigid specifications. These cables have high strength, high resistance to bending fatigue, minimum stretch and the superior flexibility of Excellay Preformed Construction. They are used on all types of planes from fighters to heavy bombers. Write for complete information or call our nearest sales representative.

The Boeing 707 jet airliner ushers in a new era of fast transportation when it will be possible to have lunch in New York and dinner in San Francisco.

AMERICAN STEEL & WIRE DIVISION
United States Steel, General Offices: Cleveland, Ohio
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

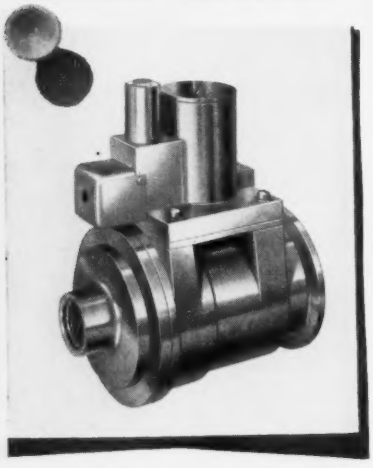
USS American Tiger Brand Aircraft Control Cables

USS

UNITED STATES STEEL

small, light, reliable
Robertshaw-Fulton
HELIUM
Pressure Regulators

Size, weight, performance—a key consideration in helium pressurization projects. Turn to R-F Aeronautical – a prime source for helium control components. Engineering experience, complete helium testing facilities... combined to meet your pressurization requirements – faster and better.



TYPICAL – this missile borne Helium Pressure Regulator with integral shut-off. INLET PRESSURE: 325±25 psig, NOMINAL OUTLET PRESSURE: 20±0.5 psia (or psig), FLOW RATE: 2000 scfm, OPERATING TEMP: AMBIENT: −65° to 165°F, GAS: −80° to 350°F, INITIAL RESPONSE TIME: 20μsec. WEIGHT: 2.75 lbs. max. DIMENSIONS: 6⅜" x3¾" x5-15/16", no flutter, chatter, overshoot, or instability.

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Sponsor: The Annual Helium Symposium

Laboratory and a daytime tour of its facilities for 200 high school students were set up by the Student Activities Committee on August 21.

Four speakers at the evening program were William L. Alford, NACA Research Pilot; Joseph Kotanchik, NACA Structures Research Division; J. A. Roche, Air Force Development Field Office; and Thomas Blair, Goodyear Aircraft Corporation.

Mr. Alford's discussion of high-speed flight programs at Langley was illustrated with films. Mr. Kotanchik discussed and showed films of aerodynamic heating tests on structures and materials. Mr. Roche praised NACA for its contributions to aeronautics and for eliminating the need for trial and error flight tests. Mr. Blair, using films, described the Goodyear Inflatoplane.

The high school students, accompanied by science teachers and Section members, visited wind-tunnel and flight facilities at Langley. Detailed talks and demonstrations covered progress in such major problems as heating at hypersonic speeds, interference at supersonic speeds, and how to reduce the length of take-offs and landings.

Edward C. Polhamus, Committee Chairman, welcomed the guests and explained the purpose and activities of the Institute.

PAUL A. HUNTER, *Secretary*

Indianapolis Section

Structure of Space "Drawn" by Hlavaty

Vaclav Hlavaty, world-prominent figure in the field of geometry, discussed "The Structure of Space and Gravity" before 150 members and guests at the first fall meeting on October 11.

Dr. Hlavaty is a Professor of Mathematics and member of the Graduate Institute of Mathematics and Mechanics of Indiana University.

He traced the evolution of geometrical hypotheses by early mathematicians to explain or prove theories of curved finite or infinite space. He reviewed failures and limitations of these early theories, drawing an analogy to the limitations of a hypothetical two-dimensional human being (on plane) attempting to visualize three-dimensional (cubical) space.

Dr. Hlavaty described the advent of relativity theory in which formulas equating dimensional relationships to observed physical phenomena were developed. He also mentioned some of the astronomical means by which these formulas have been checked. Evidence which points to matter distorting the space in which we live was discussed.

He drew attention to the role of the mathematician who works with physical relationships in a "space" in which visualization and interpretation are led astray by intuitive impressions.

ROBERT E. SAFF, *Program Committee*

Kansas City Section

Boeing Jet, Stratocruiser Characteristics Compared

"The Operational Features of the Boeing 707" were compared to the 377 Stratocruiser by Jack Waddell who pinch-hit for A. M. Johnston at the September 17 dinner meeting. Mr. Waddell is an Experimental Test Pilot and a member of Mr. Johnston's staff at Boeing.

Speaking from the pilot's point of view, he covered characteristics studied during normal sequence of take-off, climb, cruise letdown, and landing approaches. He also reviewed briefly recent 707 flight tests and showed a film on its airport handling characteristics.

Major emphasis was placed on the take-off regime as the prime difference between the jet and conventional transport and the increased severity of "operating closer to the fence and using it up faster."

Curves were used to show comparisons between the 707 and 377 for lift coefficient against angle of attack, climb rate against true air speed, acceleration characteristics against true air speed, and ability to clear 50-ft. obstacles against runway length.

Possible use of special pilot aids such as acceleration recorders to permit abortion of take-off at the earliest possible time when necessary was discussed.

The need for variable approach speed requirements in an airplane with such wide gross weight spread and vision as the 707 was reviewed along with recent successes with inlet, noise suppression, and autopilot equipment.

During the business portion of the meeting the Section revised its meeting night to the fourth Tuesday of the month, pending a review of speaker commitments already made.

The Section's advisory board and officers were introduced to the 77 members who attended this first meeting of the 1957–1958 season. Committee chairmen introduced their committee members and discussed future plans.

The IAS Flight Test Engineering Fellowship and coming IAS national meetings also were announced.

J. R. MACPHERSON, *Secretary*

Los Angeles Section

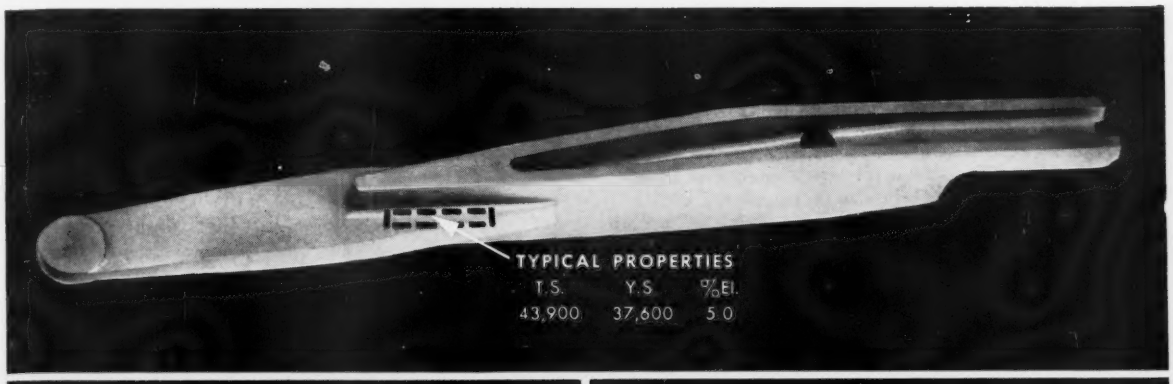
Los Angeles Reports Four Meetings in September

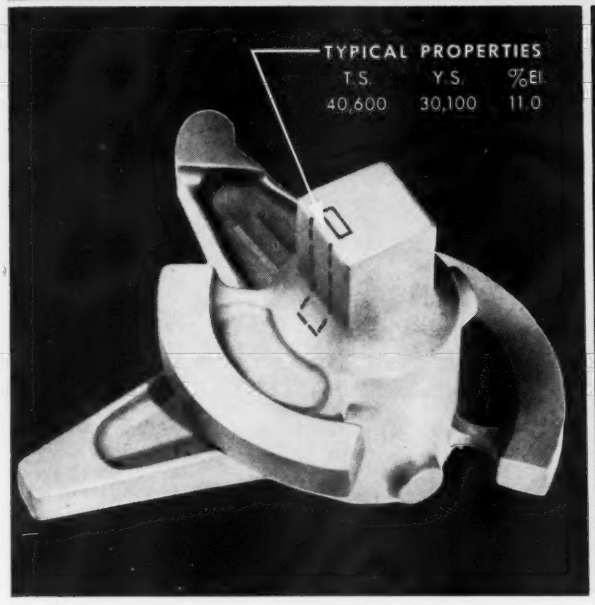
Rolf Landshoff, Consulting Scientist, Nuclear and General Physics Division, Lockheed Aircraft Corporation, discussed the interaction between magnetic fields and moving gas plasma at the September 24 specialist meeting.

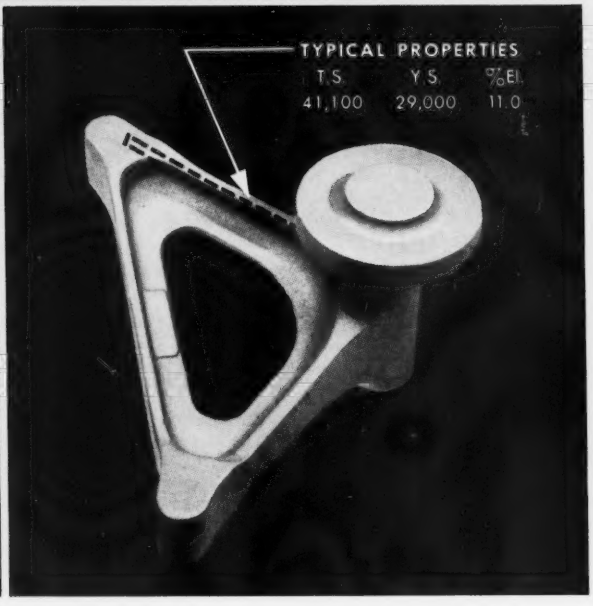
Dr. Landshoff's talk covered magneto-hydrodynamics state of the art. He reported developments in the properties of ionized gases and derived some of the flow properties.

▶ Three speakers discussing fighter aircraft during the September 19 meeting were Col. John N. Jeffers, USAF (Ret.), Col. Thomas G. Lamphier, Vice-President, Convair, and Col. Walker M. Mahurin, Director, Military Relations, Northrop.

HIGH-STRENGTH ALUMINUM CASTINGS







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Production at Brake Shoe's new aluminum foundry in Mahwah, New Jersey, is devoted to aircraft and missile parts. Improved methods, developed in two years of pilot production, have given higher quality castings in both high-strength and commercial grades. Reliable casting soundness substantially eliminates the reject problem for customers who have switched to Brake Shoe. For more information on aluminum castings by Brake Shoe, write for our booklet "Ductaluminum 356."

GUARANTEED PROPERTIES IN HIGHLY STRESSED AREAS

	T.S., psi	Y.S., psi	%El.
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AMERICAN Brake Shoe COMPANY

LIGHT METALS DEPARTMENT
MAHWAH, NEW JERSEY

The discussion was organized by the Section's Historical Committee and Dinner Meeting Committee and represented the fighter experiences of the three officers.

Colonel Jeffers served with the 94th Aero Squadron (Hat-in-Ring) during World War I, flying both Nieuport and Spad aircraft. Colonel Lamphier flew P-38's during World War II and was credited with shooting down the aircraft carrying Japanese Air Admiral Yamamota. Colonel Mahurin shot down 26 German aircraft in World War II before becoming a prisoner and later flew F-86's in the Korean conflict where he again was a prisoner of war.

Some 200 members and guests attended the meeting which was presided over by A. J. Carah, outgoing Section Secretary. Lt. Comdr. S. Gorsline, Bureau of Ordinance Representative at Douglas Aircraft Company, was a featured guest.

▶ The annual "kick-off" dinner for Section committee members and officers was held September 12, with Carl Haddon, Chief Engineer, Lockheed California Division, and incoming Chairman, presiding.

Mr. Haddon outlined objectives for the coming year and emphasized the need for continued growth in Section activities. He recommended broadening the scope of programs and increasing membership.

New officers were scheduled for formal installation at a later meeting.

▶ Emerson H. La Bombard discussed "Design Development Program for Fatigue Resistance in the Douglas DC-8 Structure" at the September 10 specialist meeting. Mr. La Bombard is Assistant Chief, Structures Section, Douglas.

He covered design development of the DC-8 structure, specifying fatigue criteria, methods of evaluation, and the relationship between service experience and laboratory results.

H. DANA MORAN, *Secretary*

New York Section

Admiral Sides Assesses Missile-Aircraft Roles

"I hold no brief for the enthusiastic missileer who proclaims that the day is just around the corner when missiles will relegate the manned airplane to the dim distant past."

This was said by Vice-Adm. John H. Sides, U.S. Navy, before some 500 members and guests at a joint dinner meeting of the New York Sections of the IAS and American Rocket Society on October 18. He is Director, Weapons System Evaluation Group, office of the Secretary of Defense.

He added to the above saying, "Certain tasks will be taken over by missiles in the not too distant future. In other tasks the timetable will be a much longer one. And in other tasks it may never come to pass."

He covered different missile systems from the view of growth potential, and of the surface-to-surface group said, ". . . once (they) become truly operational, they will year by year assume a more important role and assume a greater and greater portion. . .of the job to be done."

He said, "If we should find ourselves in a predicament where the accuracy of the combination bomber-missile system were comparable to that of a long-range surface-to-surface missile system, this could greatly influence the decision as to the timing of the transition from the manned bomber to the surface-to-surface missile."

Admiral Sides assessed current trends influencing the missile program future from seven categories. These were: *multiple approaches*—"future missile systems will embody one or a combination" of already successful guidance systems; *crash programs*—"high risks as well as a general use of overtime will in the future be avoided, except in very special cases"; *developer-user relationships*—development of ground support equipment, production capacity, logistic support, and training program systems "are the real tasks which confront us. . .(which) should be developed by the service" using the system; *reliability and maintainability*—are the outstanding characteristics required in a missile system; *complexity and cost*—perhaps service requirements are overestimated and manufacturers' promises fulfilled at a cost of too much complexity; *training*—"I believe that, upon the initiation of every new missile project, one of the requirements must address itself to the subject of training devices"; *selectivity*—a system must be evaluated from an overall-situation viewpoint covering other systems, theater of operations, task objective, and national defense application.

His comment on Russia's earth satellite was "launching of 'Sputnik' was at the expense of their ICBM program." He said we should not conclude that its propulsion plant equals that of an ICBM. "It does represent one component, but it is the one component which entails the least intricate and the least sophisticated technology. The guidance system is the heart of such a weapon, and placing a satellite in orbit requires only the grossest kind of accuracy compared to that required for an effective ICBM."

He concluded that SAC bombers and operational missiles are still a real deterrent to war.

Philadelphia Section

Around the Moon In Forty Hours

Captain Charles F. Gell, USN (MC), said a 40-hour manned excursion around the moon is forseeable, but travel to another planet is much further away than current articles would have us believe. Captain Gell, Director of the Air Crew Equipment Laboratory, Philadelphia, Pa., discussed "Man in Space" before 100 members at the October 2 joint meeting with the Aero Medical Association.

His discussion covered the physiological and psychological hazards man will face in outer space. These include effects of acceleration stress, artificial atmospheric environment, risk of explosive decompression, difficulties engendered by weightlessness, potential damage from cosmic radiation, probability of collision with meteoroids or space junk, and the technology of space suits. He illustrated his talk with a film and slides.

Captain Gell was introduced by Col. James K. Gray, USAF, Chief Flight Surgeon, Atlantic Division, MATS, who was honorary speaker.

New Section officers introduced were Harold Kaufman, Chairman; Frank E. Mamrol, Jr., Vice-Chairman; Welsh Godon, Secretary; and Gerald Cundiff, Treasurer.

W. WELSH GODON, *Secretary*

San Francisco Section

200 Members Visit New Lockheed Labs

The fall series of section meetings were given an auspicious start September 19 when more than 200 members were guests of Lockheed Missile Systems Division at its new research facility in Stanford Industrial Park.

Louis Ridenour, Assistant General Manager of the laboratories, delivered a welcoming address after which Daniel Bershader described the gas dynamics facilities. These include conventional shock tubes, shock tunnels, ballistic ranges, and electrical discharge shock tubes.

Ronald Smelt, Director of New Design, described shortcomings of conventional wind tunnels for conducting aerodynamic research for hypersonic missiles. He also reported that recent advances in the speed of data acquisition made it practical to perform detailed research in shock tunnels and other similar facilities having short operating times.

"Future Weight Reduction With Beryllium" was discussed by Louis Riedenger. His paper described beryllium properties which make the metal attractive for structures exposed to high temperatures.

Willis Hawkins, Assistant General Manager, explained the X-7 and X-17 missile programs and showed a color film of firings.

A tour of division facilities was conducted after the technical meeting.

ROBERT M. CRANE, *Secretary*

Texas Section

Air-Power Planning: A Tricky Balancing Act

The main problem of air-power planners is maintaining a balance between economy and military strength, according to Lt. Gen. Roger M. Ramey, USAF (Ret.). General Ramey spoke on "The Role of Planning in Air Power" at the September 27 meeting.

He said that our military planners must constantly evaluate the revise their plans in the light of weapon technology and economic capability of the nation. It will be increasingly necessary for planners to be more selective in the choice of new weapons to be developed, and such a choice will have to take place in the early development stage rather than when full production is imminent or in actual progress. As a result, planners are faced with greater responsibility and greater significance attached to their decisions.

Before General Ramey's talk, new officers were installed. They are C. L. Turner, Chairman; A. T. Clemen, Vice-Chairman; M. V. Riccius, Secretary; and R. E. Darling, Treasurer. Outgoing Chairman R. J. Patton reviewed last

Vertol helicopter completes longest most northern mission

FM COMDR 55TH AIR RSQ SQ THULE AB GRNLD
TO VERTOL AIRCRAFT CORP MORTON PA
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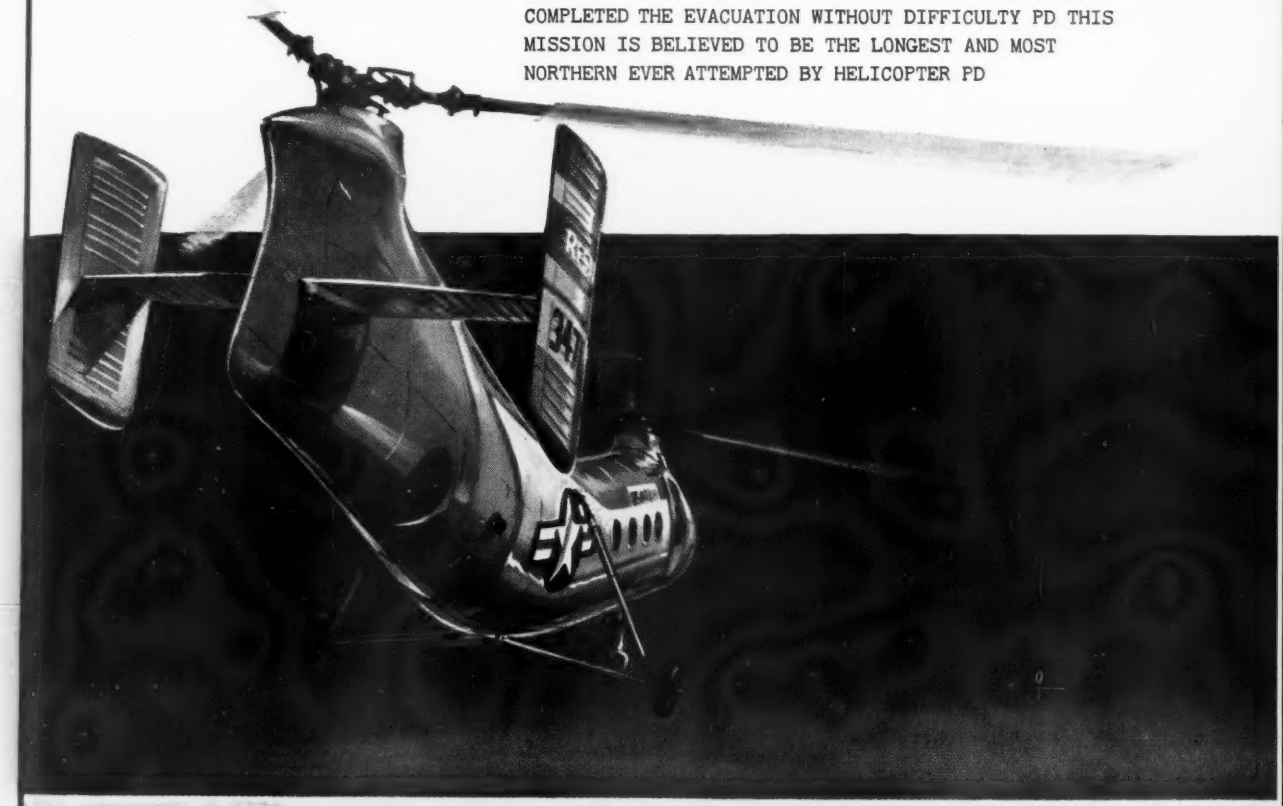
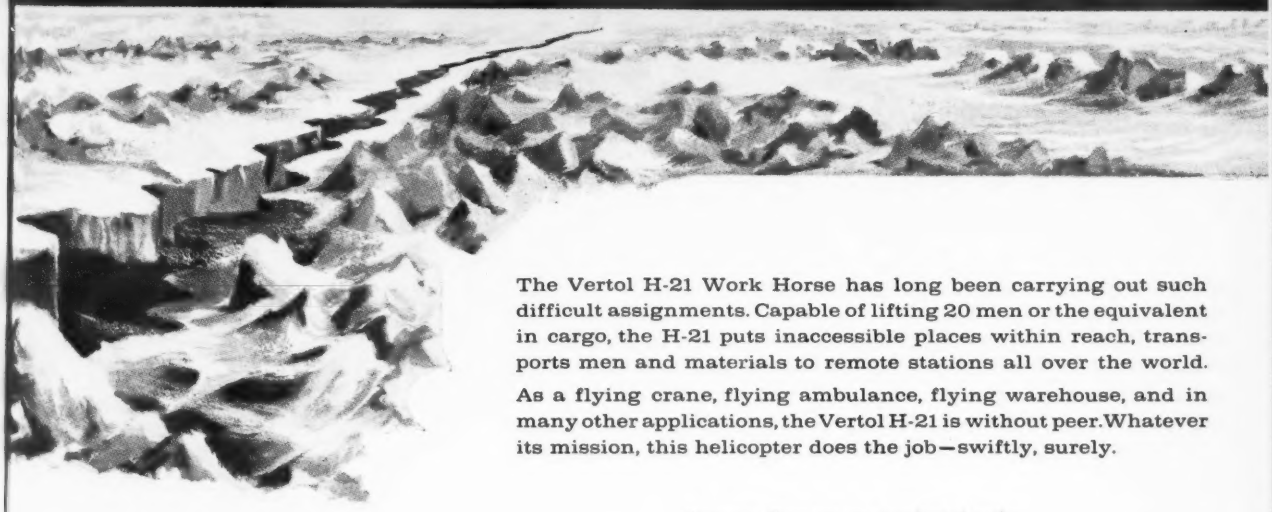
A VERTOL H-21 HELICOPTER MANNED BY THE 55TH AIR RESCUE SQUADRON AT THULE GREENLAND COMPLETED THE FIRST HELICOPTER LANDING EVER MADE ON ICE ISLAND T-3...THE VERTOL H-21 WAS ASSIGNED THE TASK OF EVACUATING TEN CIVILIAN PERSONNEL PD THE TERRAIN ON T-3 WAS SUCH THAT WHEEL OR SKI LANDINGS WERE IMPOSSIBLE PD HOWEVER THE VERTOL H-21 HELICOPTER COMPLETED THE EVACUATION WITHOUT DIFFICULTY PD THIS MISSION IS BELIEVED TO BE THE LONGEST AND MOST NORTHERN EVER ATTEMPTED BY HELICOPTER PD





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VERTOL Aircraft Corporation

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year's activities and wished the new officers success.

Test Pilot Describes Spin Test Experiences

D. A. Schultz, Senior Staff Experimental Pilot, Chance Vought Aircraft, discussed "Post Stall Behavior of High Speed Aircraft" before 100 members and guests at the September 11 meeting of the Texas Section.

He said test pilots were particularly interested in high-speed forward acceleration imposed by high rotational velocities in one spin mode. Model tests predicting this effect led to an extensive development program on means to support the pilot properly. This resulted in special head and body harness to keep the pilot from bouncing around the cockpit.

During the program it was discovered that a pilot can become acclimated to spinning, resulting in a reduction of physiological and psychological effects. Some 400 turns in a 10-day period established a plateau of acclimatization. A few spins every day or 2 maintained the plateau, but after 2 weeks' layoff, it took some 200 turns to re-establish the plateau.

Films of "post stall gyrations" in an F7U aircraft and of a pilot during a 32-turn inverted spin from which he eventually ejected were shown.

Questions from the audience brought out the importance of investigating spin characteristics. Also, the average service pilot was advised to avoid such flight conditions. However, he should be instructed on recovery techniques.

A. T. CLEMEN, *Secretary*

STUDENT BRANCHES

Brown University

Members elected a new slate of officers at an organizational meeting held September 12.

New officers are: Robert L. Sierakowski, Chairman; Richard A. Dornon, Vice-Chairman; and Daniel C. Dunlap, Secretary and Treasurer. Scott Lee Garrett, former Chairman, and Alfred A. Ramos, former Treasurer, retired necessitating the election.

By unanimous vote of all members of the Branch and its ASME counterpart, their individual meetings will be replaced by joint meetings.

DANIEL C. DUNLAP, *Secretary*

California State Polytechnic College

Some 150 members and guests heard James Wenzel outline design stages of a production aircraft. Mr. Wenzel is an aerodynamicist for Convair, A Division of General Dynamics Corporation, and a past chairman of the IAS San Diego Section.

He used slides of Convair's design test facilities to illustrate his talk. Later, he discussed how "the IAS helps bridge the gap between college and industry." He said membership in the IAS helps to bring out leadership ability, develops self-confidence, and in general prepares the student for the transition from the textbook to the engineering team. After the talk, a film on the North American Air Defense Command was shown.

The Branch Chairman Mike Daitch discussed principal coming events including the Regional Student Conference.

JERRY MITVALSKY, *Secretary*

Indiana Technical College

Plans for a field trip—Allison Engine Plant at Indianapolis first choice—were made at the October 1 meeting. The date will be announced later.

A film, *Holiday in Hawaii*, produced by United Air Lines, was shown after the business meeting.

▶ New officers were formally installed before 40 members at the first meeting of the fall on September 17. They are Duane Hoffman, Chairman; Ray Hoffman, Vice-Chairman; Herbert Krediet, Secretary; and Darl Musgrove, Treasurer.

Two films shown were *Flying Action* about the history of flying and *The ABC of Jet Propulsion* which explained and illustrated basic principles embodied in a jet engine.

HERBERT D. KREDIET, *Secretary*

▶ At the August meeting, F. Gordon Sholes, Jr., a Group Engineer on Project Vanguard, reviewed the background of the program to launch an earth satellite.

Mr. Sholes discussed the mechanical controls of the launching vehicle. He described the system which will move the first- and second-stage engines in their mountings to direct the vehicle's flight, the auxiliary jets to control pitch and yaw, and the device which will spin the third stage to stabilize the vehicle.

JACK BOCCALEONI, *Secretary*

North Carolina State College

New officers for the 1957–1958 school year were introduced at the first fall meeting on September 24. They are James Daughtridge, Chairman; Gerald Hunt, Vice-Chairman; John Gurley, Recording Secretary; Jack Wood, Treasurer; and Larry Royster, Program Chairman.

They discussed speakers for future meetings, Branch participation in the Engineer's Fair, and the regional student conferences.

A film, *Lethal Progress*, was shown. It depicted development of the Scorpion series of aircraft from prototype to the latest model. Special attention was focused on different armament systems used.

RICHMOND P. BOYDEN
Corresponding Secretary

Parks College of Aeronautical Technology

Sixteen members were present for the inauguration of new officers at the September 25 meeting.

Officers elected were Merle Allen, Chairman; Lawrence Frederick; Vice-Chairman; and Hung-Cin Hor, Treasurer. Because of unforeseen vacancies on the staff, a special election was held.

Mr. Allen discussed plans for coming meetings during the semester. For the most part, this involved ways and means of promoting greater interest in meetings.

GERALD E. CHMIELEWSKI
Secretary

The Pennsylvania State University

The 1957–1958 Branch program and objectives were discussed before 35 members at the September 26 meeting.

Chairman Robert Dunkelberger welcomed the members and reported on a successful summer program in which companies in the aircraft business were asked to provide speakers for future meetings in the school year.

Faculty Adviser John Fox explained responsibilities of the Branch as host for the 1958 Mid-Atlantic Regional Conference scheduled for next spring.

Later, a film titled *Air Age* was shown.

ROBERT E. HENDERSON
Secretary

Rensselaer Polytechnic Institute

Jim Cooley spoke on "Design Considerations of a Mach 2.5 Fighter Aircraft" before 65 members and faculty at the September 25 meeting. Mr. Cooley is a Supervisor in the Aircraft Preliminary Design and Performance Section, United Aircraft Corporation.

Some of these considerations were: the duties of the Mach 2.5 fighter of the future, structural weight, and the size of the power plant. He explained some of the ground rules a designer must establish, especially in connection with fuel consumption. After the talk he answered questions from the audience.

Later, Chairman Arthur Sutherland outlined advantages of IAS membership. Fifty membership applications and 20 subscriptions to the AERONAUTICAL ENGINEERING REVIEW were accepted.

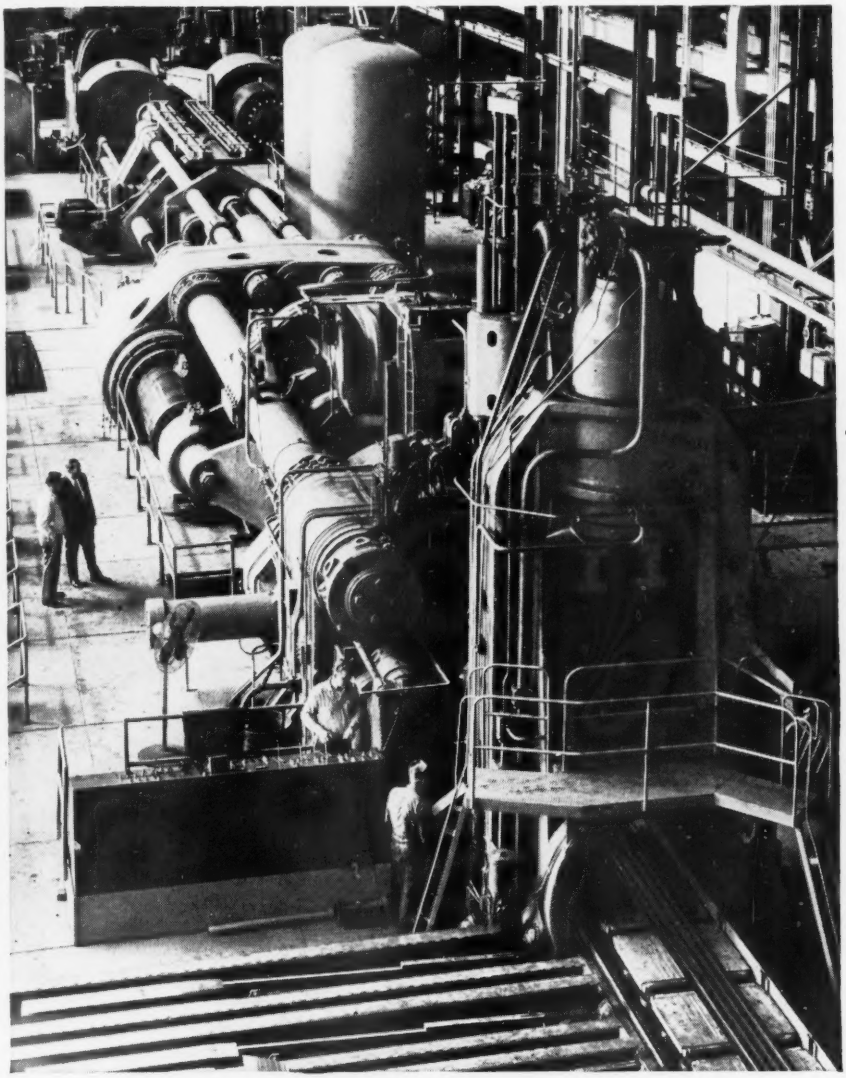
CHARLES KROMER
Secretary-Treasurer

Tri-State College

Some 75 members, faculty, and guests met in the aeronautical laboratory for the introduction of new officers at the September 26 meeting.

New officers are Donald Scharf, Chairman; Eugene Prue, Vice-Chairman; William Berg, Secretary; and Bruce Bidelman, Treasurer. Also introduced were Tri Angle reporter Robert Pemberton and Student Council Representative Jack Ebersol.

Attendance certificates were awarded to members who had attended at least 75 per cent of meetings for three consecutive



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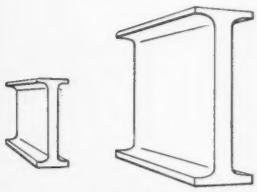
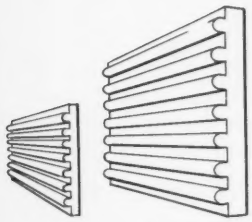


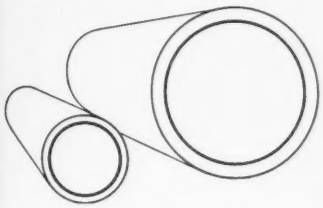
FROM 11" TO 28"

STRUCTURAL SHAPES



FROM 9" TO 20"

STIFFENED SECTIONS



FROM 10" TO 24" O. D.

TUBING

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Here's a whole new range of large magnesium extrusions:
24-inch O. D. Tubing 28-inch I-Beams 80-foot-long sections

This mammoth press, newest addition to The Dow Chemical Company's rolling and extrusion mill at Madison, Illinois, is the world's largest magnesium extrusion facility. Its vastly increased capacities afford new opportunities for designers working with light metals. A wide variety of new magnesium applications for aircraft, missile, military and general industrial use are now possible and practical. In addition to extruding magnesium, the press is also available for large aluminum extrusions.

Here's how the big press will increase maximum dimensions of representative magnesium extrusions: Integrally stiffened sections, from 9 to 20 inches wide; I-Beams from 11 to 28 inches high; round tubing from 10 to 24 inches outside diameter; and maximum lengths of 80 feet. A large number of shapes and forms can be produced, limited only by the design of the die through which the metal is extruded. Many complex shapes that formerly required separate operations can now be formed in one operation.

If your design calls for large magnesium or aluminum extrusions, contact the nearest Dow Sales Office or write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department MA 1406C-1.

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quarters. These members were Fredrick Dean, Gene Kiser, Robert Spalding, Fredrick Whitesel, and Donald Dyer.

Officer certificates were awarded to John Espey, John Luther, Donald Zurfluh, Ralph Haglock, William Berg, and Jack Ebersol for their service during the summer term.

Charles Libove, Faculty Adviser, discussed benefits of IAS membership and urged all new aeronautical students to become members.

Later, a movie, *Engineering for Tomorrow*, was shown. This covered problems in missile development at North American Aviation, Inc.

WILLIAM F. BERG, *Secretary*

University of Oklahoma

The *First Flight Tests of the B-58* were shown on film to 110 members and guests at the October meeting. Static engine runs, taxi characteristics, and the first actual flight were shown.

New officers for the fall semester were introduced during the business portion of the meeting. They are Joseph Noyes, Chairman; George Calbert, Vice-Chairman; and Wanda Little, Secretary-Treasurer.

WANDA J. LITTLE, *Secretary*

University of Wyoming

Two Senior members, David F. McVey and William C. Reed, were featured speakers at the October meeting. They described experiences at aeronautical organizations where they worked during the summer.

Mr. McVey, assigned to NACA Ames Aeronautical Laboratory, Moffett Field, Calif., described his duties on the 8 × 7 ft. Unitary-Plan Wind Tunnel. Mr. Reed described his job as draftsman in the 707 Structures Group at Boeing Airplane Company, Seattle.

During the business portion of the meeting the Treasurer's report was heard and the Branch meeting date established as the first Tuesday of each month. Plans for the annual engineering open house were discussed.

ROBERT J. MILLER, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Calvo, Rafael, Dir. Gen., Instituto Nacional de Técnica Aeronáutica, Madrid.

Hafstad, Lawrence F., Ph.D. in Physics, V-P, Research, General Motors Corp.

Lambert, Derek J., Chief Devel. Engr. (Civil), Vickers-Armstrongs (Aircraft) Ltd.

Pearcey, Herbert H., B.S. in Math., Principal Scientific Officer, National Physical Lab.

Vogt, Richard, Ph.D., Sr. Scientist; Manager, Design Dept., Aerophysics Development Corp. (Santa Barbara).

Weeks, Lawrence M., M.S. in Appl. Mech., Chief of Preliminary Design, McDonnell Aircraft Corp.

Transferred to Associate Fellow Grade

Arms, Richard P., M.S. in M.E., Mgr., CES Objectives and Programing, General Electric Co. (Evendale).

Blumenthal, Vaughn L., B.S. in Chem., Proj. Engr., Boeing Airplane Co. (Seattle).

Christensen, Horace H., B.S. in M.E., Mgr., Advanced Applications, General Electric Co. (Johnson City).

Clayman, Herbert S., B.S. in C.E., Staff Engr., Operational Factors, Boeing Airplane Co.

Edholm, Robert M., M.S. in Ae.E., Chief, Military Liaison, Temco Aircraft Corp.

Evvard, John C., Ph.D. in Physics, Chief, Propulsion Aerodynamics Div., Lewis Flight Propulsion Lab., NACA.

Petersen, Alfred H., Producibility Methods Engr., Lockheed Aircraft Corp. (Burbank).

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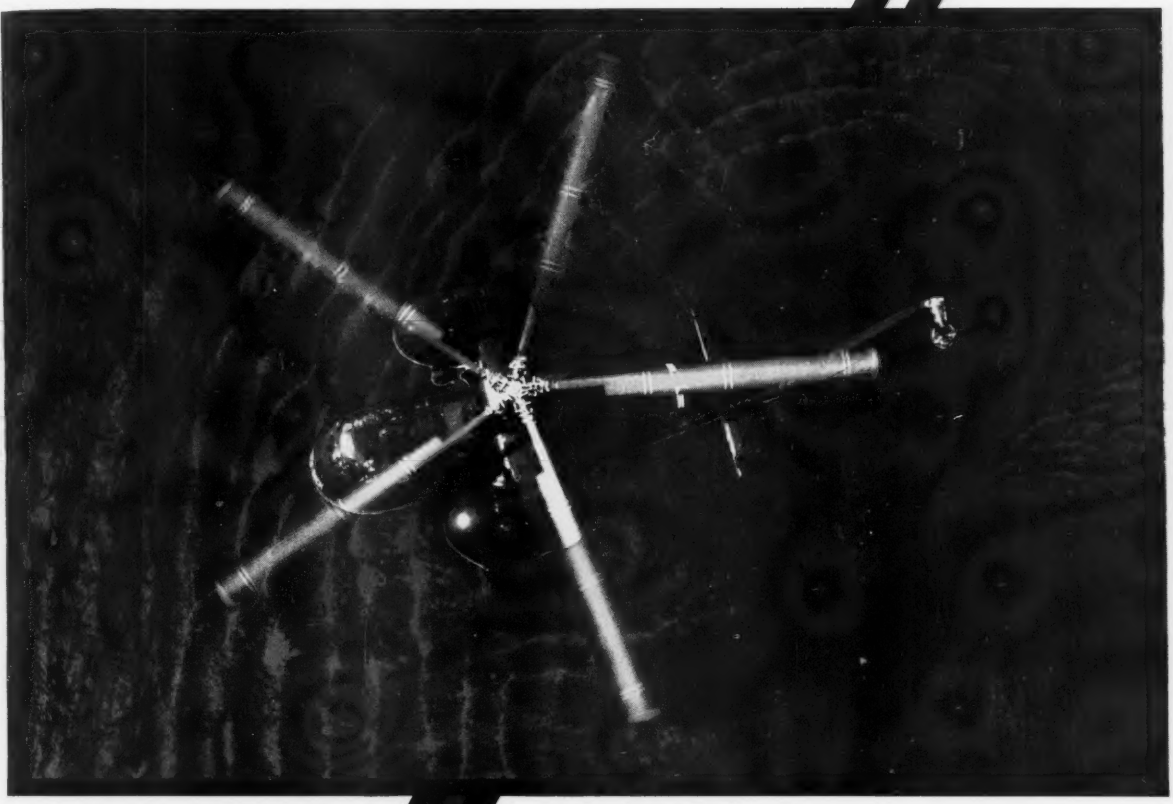

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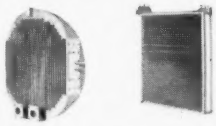

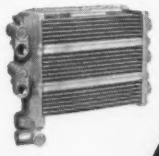

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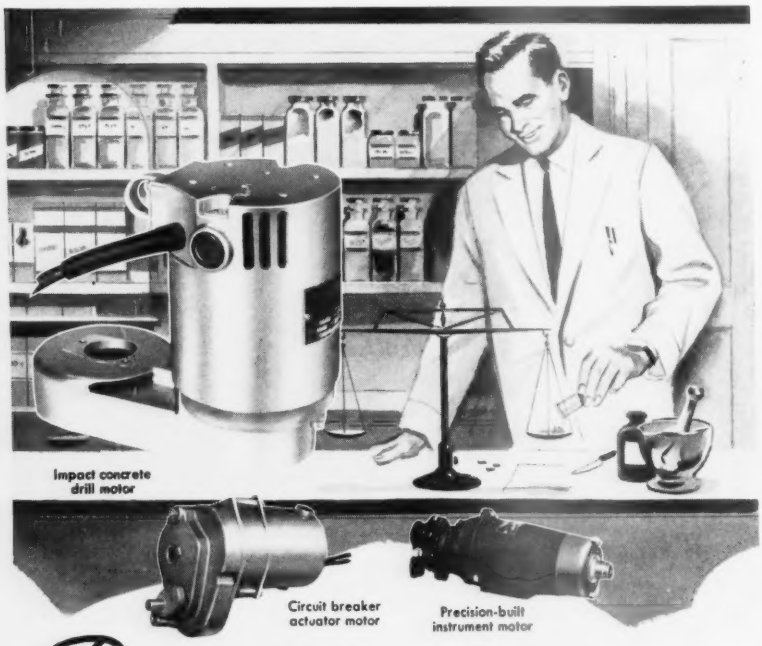

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*28E16-1	20	4	11	8.25	5700-6300	60	AND 10266 XVI-A
*28B23-1	20	4	11	8.25	4800-7200	65	AND 10262 XII-A
*28E17-1	30	8	14	8.25	5700-6300	69	AND 10266 XVI-A
*28E14-1	40	5	14.5	9.25	5700-6300	83	AND 10266 XVI-A
*28E15-1	60	6	16	9.25	5700-6300	103	AND 10266 XVI-A
28E19-1	10	4	7	6.5	7600-8400	30	AND 10262 XII-A
28E19-3	10	4	7	6.5	7600-8400	31	New 9" Flange
28E20-1	20	6	8.5	6.5	7600-8400	45	AND 10262 XII-A
28E20-3	20	6	8.5	6.5	7600-8400	46	New 9" Flange
28E21-1	30	10	12.4	6.5	7600-8400	60	AND 10262 XII-A
28E21-3	30	10	12.4	6.5	7600-8400	61	New 9" Flange
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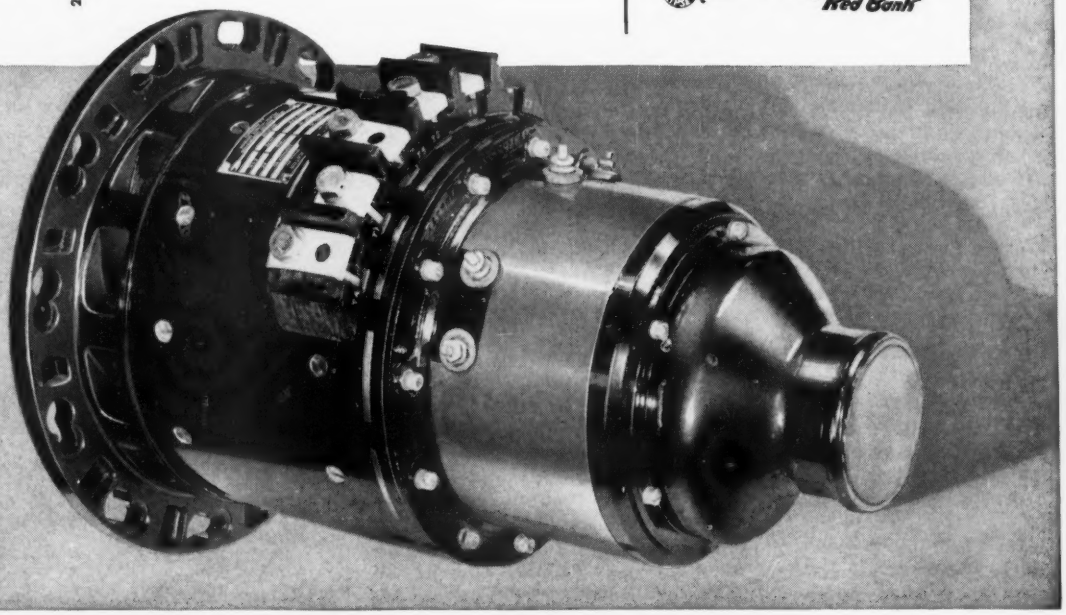

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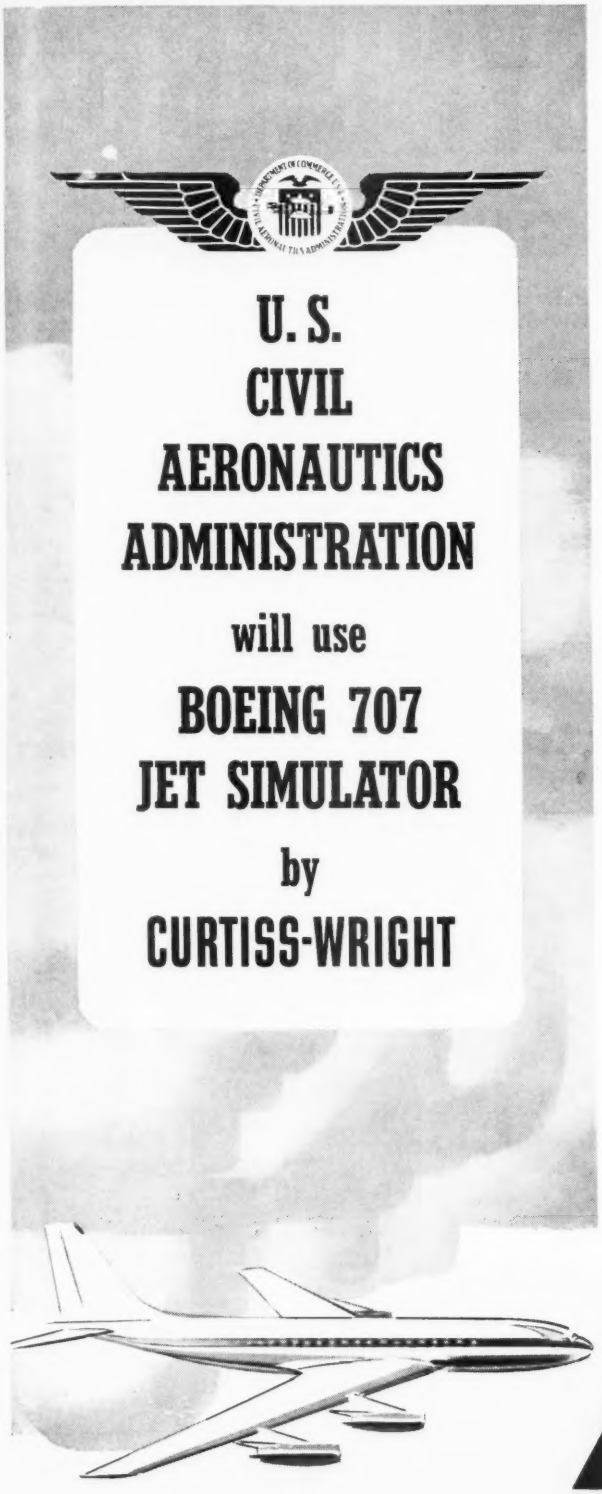

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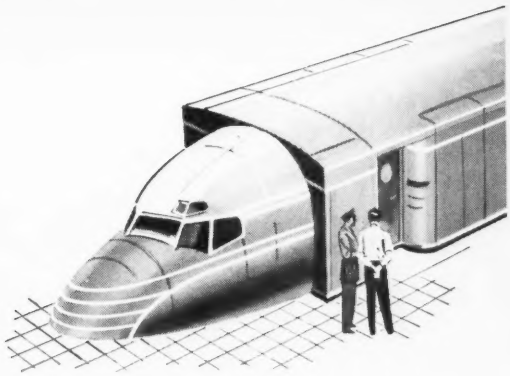

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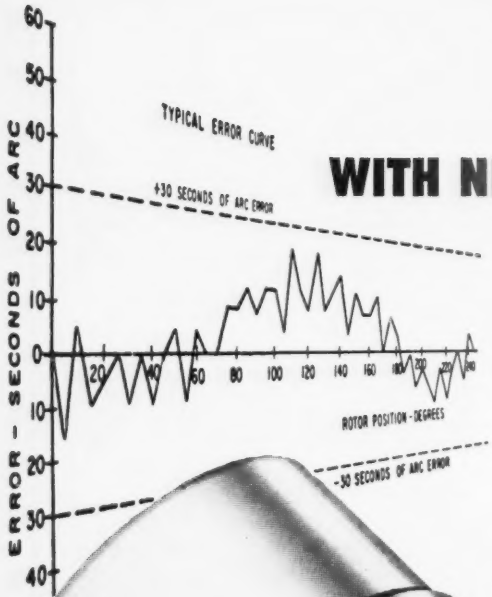

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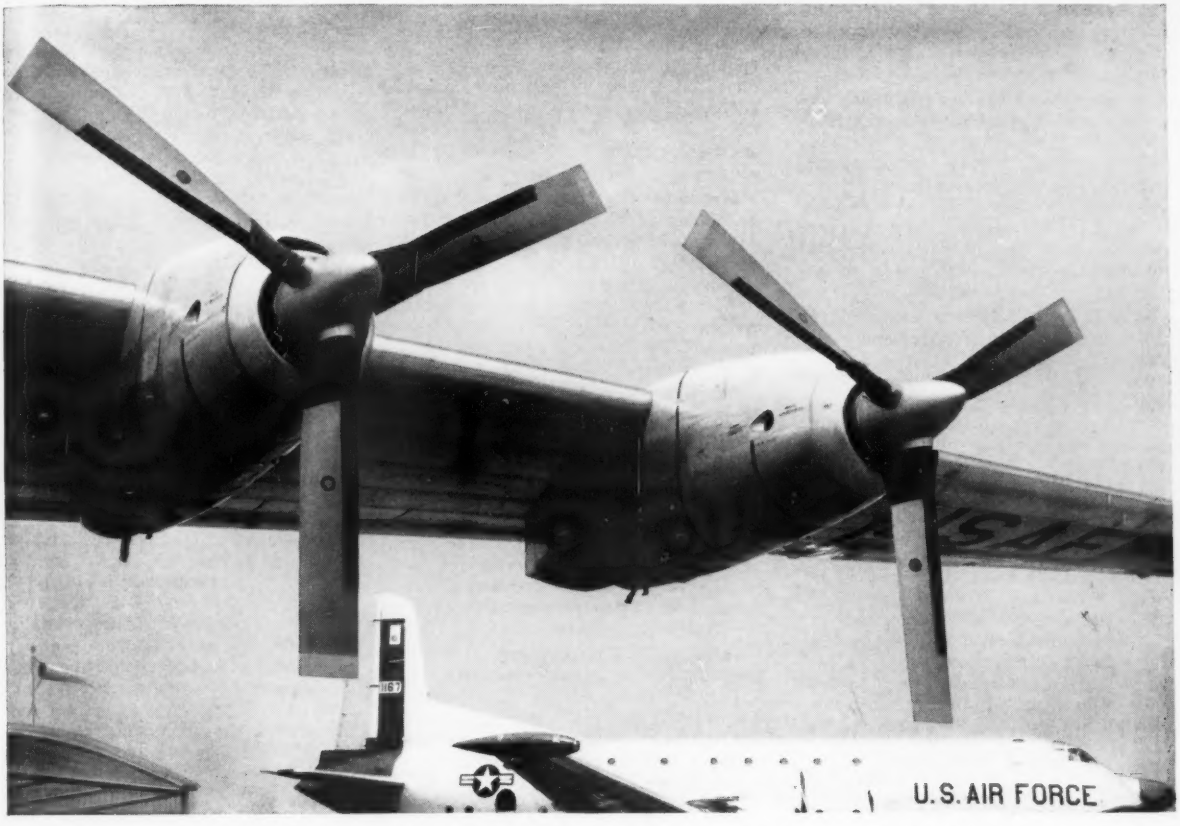

Curtiss-Wright Turbolectric Propellers on the Air Force's C-133A, world's largest turboprop cargo plane. Extruding Ni-Cr-Mo steel to form seamless hollow blades eliminates welding of blade edges and saves 200 pounds of steel per blade.

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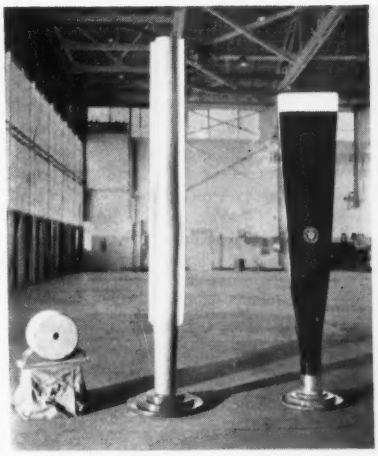

One-piece hollow blade is extruded from the billet at left, then formed by flattening and die quenching. Blade tip is closed by welding.

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profile grid in the case of nonstationary motions and discussion of the simplification of the mathematical aspect of this problem.

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(*Continued on page 112*)

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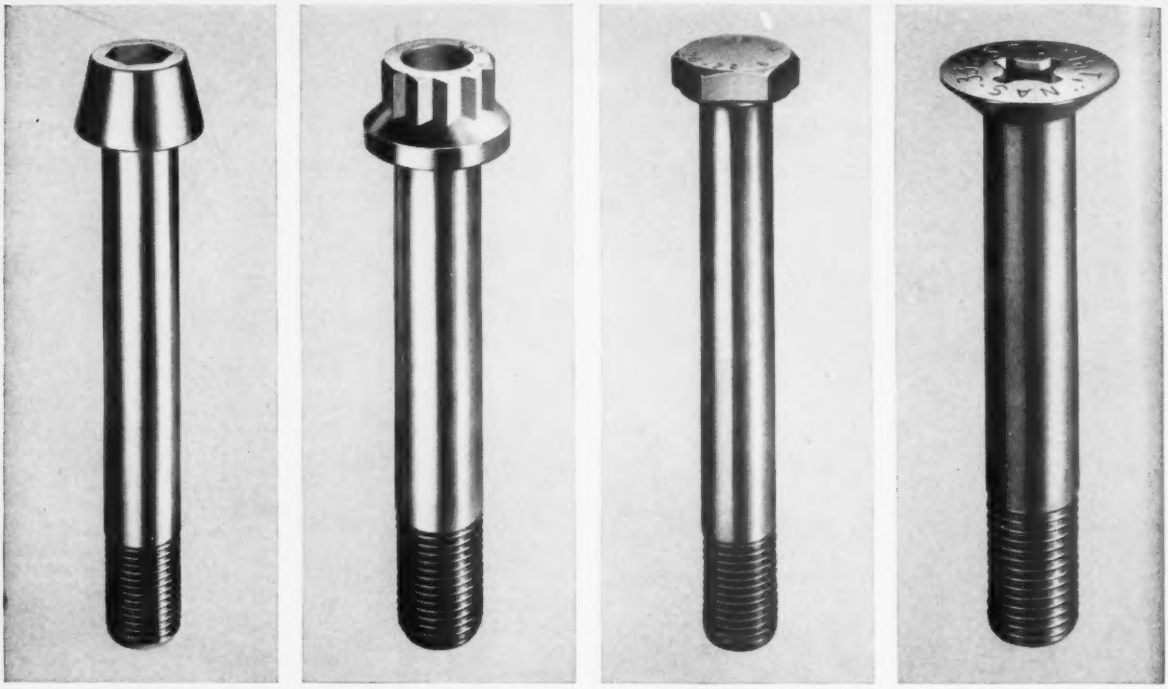

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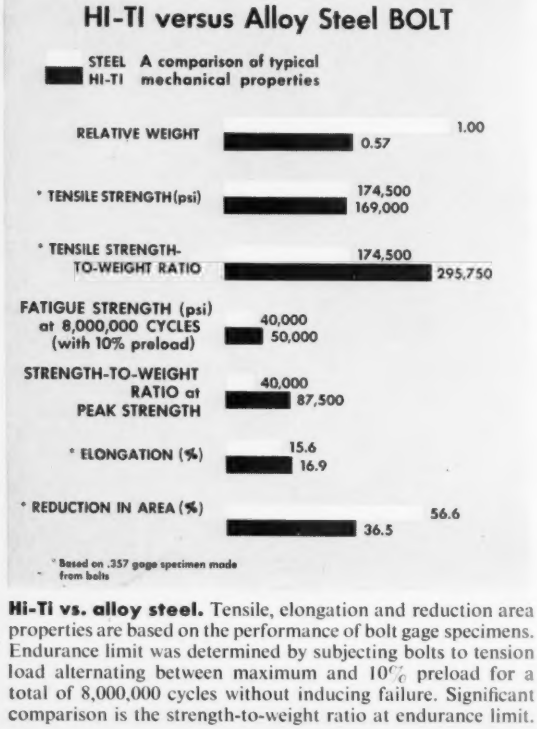

Hi-Ti vs. alloy steel. Tensile, elongation and reduction area properties are based on the performance of bolt gage specimens. Endurance limit was determined by subjecting bolts to tension load alternating between maximum and 10% preload for a total of 8,000,000 cycles without inducing failure. Significant comparison is the strength-to-weight ratio at endurance limit.

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INTERNATIONAL AERONAUTICAL ABSTRACTS

A Review of Worldwide Scientific and Technical Literature

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AERODYNAMICS

Aerothermodynamics

MASS TRANSFER COOLING OF A LAMINAR BOUNDARY LAYER BY INJECTION OF A LIGHT-WEIGHT FOREIGN GAS. E. R. G. Eckert, P. J. Schneider, A. A. Hayday, and R. M. Larson. Minn. U., Inst. Tech., Dept. Mech. Eng. HTL TN14, June, 1957. 45 pp. Analysis to determine the velocity, temperature, and concentration fields in a laminar air boundary layer on a flat plate in high-speed dissipative flow, the plate being considered porous and cooled by injection of hydrogen from its surface. The admixture of hydrogen, having a low density and high thermal capacity relative to air, is shown to greatly diminish the skin friction and to markedly relieve the adverse thermal effects of intense aerodynamic heating under conditions of hypersonic flow.

INFLUENCE OF TURBULENCE ON TRANSFER OF HEAT FROM CYLINDERS. J. Kestin and P. F. Maeder. US, NACA TN 4018, Oct., 1957. 78 pp. 36 refs. Measurement of the overall (mean) coefficients of heat transfer at very low Mach Numbers and large Reynolds Numbers. Results, which are presented in the form of curves for Nusselt Number vs. Reynolds Number and Stanton Number vs. Reynolds Number (all based on mean properties), indicate that turbulence not only has the effect of shifting the point of laminar separation in subcritical flow or the point of transition in supercritical flow: varying the free-stream turbulence is shown to affect also the local rates of heat transfer. A survey of related analytical and experimental work is included which shows that the present conclusions find ample support in previous investigations.

EXPERIMENTAL INVESTIGATION OF TRANSPIRATION COOLING FOR A TURBULENT BOUNDARY LAYER IN SUBSONIC FLOW USING AIR AS A COOLANT. W. E. Brunk. US, NACA TN 4091, Oct., 1957. 35 pp. Tests to determine the effect of injecting coolant air through a porous sintered bronze plate into a constant-area tunnel through which hot air is flowing. Results show that a definite correlation exists between the porous wall temperature and the injected coolant-flow rate; wall temperature decreases as coolant-flow rate increases. The correlation for a given station along the porous plate appears independent of the type of test when based on local conditions. Results are compared with those of a theory for transpiration into a turbulent boundary layer with an isothermal wall.

THEORY AND APPARATUS FOR MEASUREMENT OF EMISSIVITY FOR RADIATIVE COOLING OF HYPERSONIC AIRCRAFT WITH DATA FOR INCONEL AND INCONEL X. W. J. O'Sullivan, Jr. and W. R. Wade. US, NACA TN 4121, Oct., 1957. 48 pp. 12 refs. Calculations of the amount of cooling attainable by radiation at Mach Numbers up to eleven and altitudes up to 100,000 ft. presented for a flat plate with turbulent boundary layer aligned with the wind. The theory underlying the investigation and measurements of total hemispherical emissivity are presented..

THE HETEROGENEOUS, LAMINAR, BOUNDARY LAYER. J. R. Baron. (Mass-Transfer Cooling for Hypersonic Flight, Symposium, Santa Monica, June 24-26, 1957.) MIT NSL TR 236 (AFOSR TN 57-392) [AD 132474], 1957. 27 pp. Theoretical investigation of the general mass-transfer situation for which the fluid introduced into the high-speed boundary layer differs appreciably in physical properties from those of the external fluid flow. The descriptive system of equations is deduced from Enskog's solution of the Boltzmann equation and includes provision for component mass conservation, energy migration resulting from specific enthalpy differences, and thermodynamic coupling between the transport phenomena. A similarity analysis is presented for laminar flows with and without pressure gradients, and numerical results are given for helium and carbon-dioxide as foreign gases in a primarily air boundary layer flowing over a flat plate.

A SIMPLE MODEL OF THE NONEQUILIBRIUM DISSOCIATION OF A GAS IN COUETTE AND BOUNDARY LAYER FLOW. J. E. Broadwell. Douglas Rep. SM-22888, Aug., 1957. 62 pp. Formulation of a simple model of a gas to illustrate the effects on heat transfer of (a) the dissociation into atoms of the nitrogen and oxygen molecules in air, due to high temperatures, and (b) the formation of concentration gradients and the transfer of energy by interdiffusion of atoms and molecules - this interdiffusion resulting from nonuniform temperatures. Heat transfer is considered in three situations: in a layer of gas at rest between two walls at different temperatures, in Couette flow, and in a boundary layer on a flat plate. Two chemical conditions of the walls are considered, and a mechanical analogy to the stationary and Couette flow problems is developed which provides a means of visualizing the influence of the parameters and boundary conditions on the temperature and concentration profiles.

Boundary Layer

THE STABILITY OF BINARY BOUNDARY LAYERS. Appendix A - A DISCUSSION OF THE BOUNDARY CONDITIONS AND ASSUMPTIONS IN A BOUNDARY LAYER FLOW WITH INJECTION OR SUCTION. E. E. Covert. MIT NSL TR 217 (AFOSR TN 57-200) [AD 126497], June, 1957. 30 pp. Calculations based upon boundary-layer stability equations linearized according to Dunn and Lin's treatment. Results indicate that, for relatively small injection rates which ensure the validity of the boundary-layer approximation, the stability can be calculated for the binary boundary layer and for an n-component boundary layer in the usual way (based upon the steady-state velocity and density profiles) without additional complications due to the added equations.

ASYMPTOTIC INTEGRATION OF SHOCK TUBE BOUNDARY LAYER EQUATIONS. W. Lick. Rensselaer Polytech. Inst. Dept. Aero. Eng. TR AE5705 (AFOSR TN-57-610) [AD 136600], July, 1957. 13 pp. Integration of the compressible boundary layer equations for the case of a shock wave propagating into a stationary fluid, bounded by a wall, by an asymptotic method, first introduced by Meksyn for the usual case of a compressible boundary layer on a semi-infinite plate. Arbitrary constant Prandtl Number and viscosity proportional to the temperature are assumed. Simple algebraic equations are obtained from the momentum and energy equations.

THE LAMINAR BOUNDARY-LAYER FLOW ON ROTATING CYLINDERS. I - FLAT PLATE. Shao-Wen Liu. Cornell U., Grad. Sch. Aero. Eng. Rep. (AFOSR TN 57-298) [AD 132369], June, 1957. 56 pp. 12 refs. Extension of boundary-layer equations for a rotating blade and their solutions to allow the axis of rotation to be arbitrarily located with respect to the loading edge of the blade. For the case of a flat plate, two parameters are used to construct the boundary-layer flow at various locations on the plate with respect to the location of the axis of rotation. A perturbation procedure is set up by expressing the velocity components in series expansions of the parameters. Successive orders in the velocity components are obtained by numerical integration.

EXPERIMENTS ON BOUNDARY-LAYER TRANSITION AT SUPERSONIC SPEEDS. E. R. van Driest and J. C. Boison. (USAF OSR TN 55-465, Sept. 1, 1955.) J. Aero. Sci., Dec., 1957, pp. 885-899. Investigation to determine the effects of surface cooling on boundary-layer transition. The study was made at test section Mach Numbers of 1.97, 2.81, and 3.84 with an internally cooled 20-in. 10° (apex angle) smooth cone in the presence of three levels of supply-stream turbulence (0.4, 2, and 9 per cent) and with several single-element roughnesses at fixed axial location. Transition data are obtained optically by means of a magnified-schlieren system. The results indicate that (1) transition on a smooth cone can definitely be delayed by surface cooling, (2) transition promoted by either supply-stream turbulence or surface roughness can also be delayed by surface cooling depending upon degree of turbulence or relative roughness, respectively, and (3) the adverse effects of increased turbulence and roughness decrease with increasing Mach Number.

STABILITY OF LAMINAR BOUNDARY LAYER NEAR A STAGNATION POINT OVER AN IMPERMEABLE WALL AND A WALL COOLED BY NORMAL FLUID INJECTION. M. Morduchow, R. G. Grape, and R. P. Shaw. US, NACA TN 4037, Aug., 1957. 56 pp. 35 refs. Theoretical determination of minimum critical Reynolds Numbers for laminar instability of two-dimensional stagnation flows over a wall cooled by normal fluid injection. The individual as well as the net effects of wall temperature and normal fluid injection on the stability characteristics of the laminar boundary layer are thereby investigated. In order to study the effect of the favorable pressure gradient in this type of flow, comparison is made between results of calculations obtained herein and results of similar calculations for the flow over a flat plate. Treatment includes comparison of various stability criteria, and, for certain cases of normal mass-flow injection, a slight appropriate extension in the approximate stability criteria is made.

SOME FURTHER JET FLAP EXPERIMENTS. N. A. Dimmock. Gt. Brit., ARC CP 345, 1957. 70 pp. BIS, New York, $1.62. Presentation of results of tests on a two-dimensional airfoil having a 12.5% thick elliptical cross section with a narrow full span jet slot and a jet deflection 58.1° from the chord line. Test results support the thrust hypothesis, in that the measured thrust is greater than the reaction component from the deflected jet. The airflow around the airfoil is traced by smoke streams and recorded photographically. It is therey shown that, with the airfoil at zero incidence, the entrainment of the mainstream by the jet is sufficient to cause the former to rejoin the upper surface after separation at the leading edge, even with a full chord separation bubble. Some of

these illustrations are presented, together with test results obtained at the same Reynolds Number.

Control Surfaces

EFFECTS OF ELEVATOR CIRCUIT STIFFNESS ON THE LOADING CONDITIONS IN LONGITUDINAL MANOEUVRES. Appendix I - THE EQUATIONS OF MOTION AND THEIR SOLUTION. D. R. Puttock. Gt. Brit., ARC CP 354, 1957. 31 pp. BIS, New York, $0.81. Analysis indicating that the loading conditions at the tail in a rapid pull-out maneuver may be significantly dependent on the degree of stiffness present in the elevator circuit, and that acceptance of the assumption that the circuit is rigid in the analysis of such maneuvers when it is not justifiable may lead to an underestimate of the critical loading conditions. It is suggested that the investigation may serve to illustrate a method of approach to other problems in which there exists an interaction between dynamic structural distortions and elevator hinge moments.

THE ROTATING FLAP AS A HIGH-LIFT DEVICE. Appendix I - THEORY OF AN AEROFOIL WITH ROTATING FLAP. Appendix II - POWER REQUIRED TO ROTATE THE FLAP OF A TYPICAL FOUR-ENGINED TRANSPORT. L. F. Crabtree and D. A. Kirby. Gt. Brit., RAE TN Aero. 2492, Apr., 1957. 28 pp. Presentation of the results of past research on the rotating flap, together with some further analysis. Some experimental results for an isolated rotating wing are given, and the phenomena of autorotation and of the Magnus effect are discussed. The thin airfoil theory of a wing with a rotating trailing-edge flap is developed, and experimental results for such a configuration are given. The final discussion includes a correlation between the results for the wing with rotating flap and for an isolated rotating wing.

WIND-TUNNEL INVESTIGATION AT LOW SPEEDS TO DETERMINE FLOW-FIELD CHARACTERISTICS AND GROUND INFLUENCE ON A MODEL WITH JET-AUGMENTED FLAPS. R. D. Vogler and T. R. Turner. US, NACA TN 4116, Sept., 1957. 48 pp. Investigation of jet flaps with deflections of 55° and 85° for jet-blowing energies covering a range representative of that of the output of current jet airplanes. The high lift coefficients, the drag coefficient, and the nose-down pitching-moment coefficient are all reduced when the wing is in the proximity of the ground. The adverse ground effects increase rapidly as the wing approaches, as the jet-deflection angle increases, or as the momentum coefficient increases. No ground effect is noted with either a deflection of 55° (when the model is mounted higher than 3 chords above the ground) or with a deflection of 85° (with the model mounted more than 5 chords above the ground).

WIND-TUNNEL INVESTIGATION OF EXTERNAL-FLOW JET-AUGMENTED DOUBLE SLOTTED FLAPS ON A RECTANGULAR WING AT AN ANGLE OF ATTACK OF 0° TO HIGH MOMENTUM COEFFICIENTS. E. E. Davenport. US, NACA TN 4079, Sept., 1957. 31 pp. Study in which high-momentum air is blown from one to two nacelles over the double slotted flaps of 30% wing chord, incorporating vanes of either 58.3% or 20% of the flap chord. Over the lift-coefficient range investigated these flaps produce about 80% of the lift produced by the jet-augmented plain flap. With the center of moments at 25% wing mean aerodynamic chord, large negative pitching moments are found to exist for the double-slotted-flap configurations which are comparable with those produced by the jet-augmented plain flap previously investigated.

Fluid Mechanics & Aerodynamic Theory

VARIATION OF FLOW QUANTITIES ALONG STREAMLINES AND THEIR PRINCIPAL NORMALS AND BINORMALS IN THREE-DIMENSIONAL GAS FLOWS. R. P. Kanwal. J. Math. & Mech., Sept., 1957, pp. 621-628. Discussion of the three-dimensional steady rotational gas flows of nonviscous and non-heat-conducting fluids. The purpose of the study is to investigate various dynamic and kinematic relations connecting the flow quantities with the geometric parameters of the streamline trajectories. The expressions for the tangent, principal normal, and binormal vectors and the curvature and torsion of the streamlines are given in terms of the velocity components, pressure, and density. The relations connecting the vorticity components with the gradient of entropy are also investigated. The velocity components are found in terms of the curvature of the streamlines and the velocity gradients along the streamlines and their principal normals and binormals. In plane gas flows these results reduce to the results of Crocco and Thomas.

A PROOF AND GENERALIZATION OF THE PRINCIPLE OF MINIMUM DISSIPATION. Paul Lieber and Koon-Sang Wan. Rensselaer Polytech. Inst. Dept. Geol. AFOSR TN 57-479 [AD 136471], Sept., 1957. 20 pp. Formulation of a variational principle which indicates that the principle of stationary dissipation applies to the temporal mean flow. This principle restricts the admissible rotational flow regimes in a manner not embodied in the Navier-Stokes equation. In so doing, it may give a criterion and condition for selecting, from the class of flows admissible by the Navier-Stokes equation, the observable flow. When the stationary dissipation principle is formulated for the temporal mean flow in the large, it provides a condition for calculating the joining surface. The solution of this problem is fundamental in establishing the significant domain of integration.

APPLICATIONS BASED ON VARIATIONAL PRINCIPLES FOR REAL FLUIDS. Koon-Sang Wan and Paul Lieber. Rensselaer Polytech. Inst. Dept. Geol. AFOSR TN 57-481 [AD 136473], Sept., 1957. 36 pp. Application of the "L" principle to the calculation of a real flow field about a circular cylinder in a manner which will include the determination of the extent of the rotational regime. The differential equation governing the time dependent steady state motion according to the "L" principle and the compatibility condition is investigated.

This investigation relates the temporal mean flow to the temporal fluctuations. It thereby suggests a connection with turbulent flow. The coupling of the time dependent motion and the temporal mean flow suggests the possibility of calculating inhomogeneous turbulent flows from this point of view.

MOTI A SIMMETRIA ASSIALE DI UNA MISCELA DI GAS A COMPOSIZIONE NON UNIFORME. L. G. Napolitano. L'Aerotecnica, June, 1957, pp. 129-132. In Italian. Derivation of the basic equations of axially symmetric motion for a nonreacting binary gas mixture with negligible body forces which are predicted in general curvilinear coordinates. Their application to axially symmetric motion within the boundary-layer approximation is investigated. Two simplified sets of equations are derived by taking into account the transverse curvature of the first and second approximations. By suitable definition of diffusion and energy fluxes in the Mangler plane, the Mangler transformation is extended to the subject motion.

ON ALMOST RIGID ROTATIONS. K. Stewartson. J. Fluid Mech., Oct., 1957, pp. 17-26. Investigation of flow between two coaxial rotating disks, each having an arbitrary small angular velocity superposed on a finite constant angular velocity. It is found that, if the perturbation velocity is a smooth function of r, the distance from the axis, then the angular velocity of the main body of fluid is determined by balancing the outflow from the boundary layer on one disk with the inflow to the boundary layer on the other at the same value of r. At a discontinuity in the angular velocity of either disk, a shear layer parallel to the axis occurs. If the angular velocity of the main fluid body is continuous, the purpose of this shear layer is solely to transfer fluid from the boundary layer at one disk to the boundary layer of the other.

ON PLANE AND SPATIAL SOURCE IN COMPRESSIBLE FLOW. M. Z. v. Krzywoblocki, L. Pottsepp, and M. Saarlas. Istanbul Tek. U., Bul., 1957, pp. 19-27. Presentation of various solutions for the velocity potential of a source or sink in a plane and a spatial compressible flow domain, using exact and approximate pressure density relations for isentropic fluid. Assuming a steady, irrotational, isentropic flow of an inviscid, non heat-conducting fluid, the fundamental equations on which the authors base their work are: the equation of continuity, energy, irrotationality, and that of isentropic gas.

ON THE NATURE OF THE SONIC LINE FOR SUPERSONIC AND HYPERSONIC FLOW OVER BLUNT BODIES. R. F. Probstein. Brown U., Div. Eng., USAF WADC TN 57-349 [AD 142037], Sept., 1957. 17 pp. 14 refs. Analysis indicating that, for axisymmetric flow, the body shape in the supersonic region influences the sonic line shape (and hence the subsonic flow region) at low supersonic speeds but does not influence the sonic line shape at higher Mach Numbers, the location of the body sonic point being the only surface characteristic having any influence on the subsonic region for the hypersonic problem. On the other hand, for plane flow some portion of the body in the supersonic region will influence the sonic line shape at all finite Mach Numbers, although this region of body influence will decrease with increasing Mach Number.

LOW REYNOLDS NUMBER FLOW PAST A CIRCULAR CYLINDER. Saul Kaplun. J. Math. & Mech., Sept., 1957, pp. 595-603. ONR-supported application of previously obtained results to the problem of finding a uniformly valid asymptotic expansion of the Navier-Stokes solution for incompressible stationary flow past a circular cylinder at low Reynolds Numbers. Some additional remarks are made about the general two-dimensional problem.

THE AXISYMMETRIC SUPERSONIC FLOW NEAR THE NOSE OF A POINTED BODY OF REVOLUTION. L. G. Napolitano and Antonio Ferri. J. Aero. Sci., Dec., 1957, pp. 900-904. OSR-supported development of an approximate method for the solution of supersonic flow based on the method of linearized characteristics. With this method it is possible to obtain an upper limit of the validity of the assumption that the perturbation derivatives remain finite and small throughout the flow field. Application is made to flow about the nose of the RM-10 body for several flight Mach Numbers, and the results are shown to be in good agreement with other methods of analysis.

ON THE TWO-DIMENSIONAL COMPRESSIBLE FLOW OVER A THIN SYMMETRIC OBSTACLE WITH SHARP SHOULDERS PLACED IN AN UNBOUNDED FLUID AND IN A CHOKED WIND TUNNEL. Ken-ichi Kusukawa. Phys. Soc. Japan J., Sept., 1957, pp. 1031-1041. 11 refs. Study of transonic flow in which a flow with free streamlines is used as a model, and is assumed to separate from the surface of the body at the shoulder instead of performing the Prandtl-Meyer expansion. Applying the model flow method to the flow past a finite wedge, and comparing the results thus obtained with the more accurate solutions derived by Guderly, Cole, Hida, and Marschner, it is found that the accuracy of the predicted values of the pressure distribution over the surface or the heat drag coefficient is fairly good. However, at the choking Mach Number, the model flow gives a different value from that of real flow.

VLIIANIE MALOGO ZATUPLENIIA PEREDNEI KROMKI PROFILIA NE EGO OBTEKANIE PRI BOL'SHOI SVERKHZVUKOVOI SKOROSTI. G. G. Chernyi. AN SSSR Dokl., June 1, 1957, pp. 721-724. In Russian. Study of the effect of leading-edge bluntness on the hypersonic flow around a profile using an approximate method based on the concept that in the case of strong shock waves the basic mass of gas in the disturbed region concentrates in the thin layer behind the shock wave and assuming that the mass of gas in the disturbed region moves together with the shock wave.

ON THE COMPRESSIBLE FLOW OVER A SLENDER BODY OF REVOLUTION WITH A FLAT BASE

PLACED IN AN UNBOUNDED FLUID AND IN A CHOKED WIND TUNNEL. Ken-ichi Kusukawa. Phys. Soc. Japan J., Sept., 1957, pp. 1042-1048. Comparison of the pressure coefficient on the surface of a cone at sonic speed, calculated by the model flow method, with Yoshihara's result obtained by the relaxation method. The method is then applied to several flows past a body of revolution of finite length with a curved surface.

TWO-DIMENSIONAL SUBSONIC AND SONIC FLOW PAST THIN BODIES. J. B. Helliwell and A. G. Mackie. J. Fluid Mech., Oct., 1957, pp. 93-109. EOARDC-sponsored application of hodograph methods to determine the flow at high subsonic and sonic velocities past two-dimensional, symmetrical bodies. The boundary value problem for the determination of the stream function is simplified by the assumption of a free stream breakaway at sonic velocity from the shoulder of the body. A solution is obtained in terms of Bessel functions. The flow past a wedge of small angle is also discussed, and expressions are obtained for the pressure on the nose, the drag coefficient, and the width of the wake.

INCOMPRESSIBLE POTENTIAL FLOW ABOUT AXIALLY SYMMETRIC DUCT BODIES. Philip Levine. USAF WADC TN 57-287 [AD 130967], Aug., 1957. 45 pp. 24 refs. Derivation of velocity potentials and stream functions for a point source, doublet, ring source, ring doublet, disk source, disk doublet, ring vortex, and line source for the case of axially symmetric incompressible potential flow in an infinitely long duct of constant diameter. Methods for the development of arbitrary body shapes in uniform ducted flow with a prescribed velocity and specified body coordinates are presented.

A DISCUSSION OF CONE AND FLAT-PLATE REYNOLDS NUMBERS FOR EQUAL RATIOS OF THE LAMINAR SHEAR TO THE SHEAR CAUSED BY SMALL VELOCITY FLUCTUATIONS IN A LAMINAR BOUNDARY LAYER. N. Tetervin. US, NACA TN 4078, Aug., 1957. 25 pp. 10 refs. Approximate analysis which indicates that the ratio of the cone Reynolds Number for transition (based on the distance to the cone apex) to the plate Reynolds Number for transition (based on the distance to the leading edge) is not in general equal to three, as has been suggested by other investigators. Results indicate that the ratio varies from three, when transition occurs at the minimum critical Reynolds Number, to unity, when transition occurs at a large multiple of the critical Reynolds Number.

SLENDER-BODY CALCULATIONS OF LOCAL LIFT ON SOME NON-AXIALLY SYMMETRIC BODIES WITH APPLICATION TO WIND TUNNEL HALF MODELS. Appendix I - LOCAL LIFT DISTRIBUTION FROM SLENDER-BODY THEORY. Appendix II - FLOW PRODUCED BY TWO-DIMENSIONAL ELLIPTIC BODY WHICH IS MOVING AND GROWING. Appendix III - BODIES WITH SIMILAR ELLIPTIC CROSS SECTIONS (k = CONSTANT). M. E. Graham and Z. O. Bleviss. Douglas Rep. SM-22771, Apr., 1957. 29 pp. Application of slender-body theory to the calculation of the local lift distribution on certain bodies. Bodies of a special cross section with a flat center region are investigated by means of an electrical analog, and bodies with elliptical cross sections of varying eccentricity are studied analytically. These bodies represent an idealization of a fuselage half model which is placed outside the wall boundary layer by using a skin between the model and the wall. The lift on such a half model is compared with half the lift on the full model.

LOW-SPEED EXPERIMENTAL INVESTIGATION OF THE MAGNUS EFFECT ON VARIOUS SECTIONS OF A BODY OF REVOLUTION WITH AND WITHOUT A PROPELLER. M. J. Queijo and H. S. Fletcher. US, NACA TN 4013, Aug., 1957. 68 pp. Test results which show that, with the propeller off, rotation of sections in the expanding portion of the body (nose of the body) produce no appreciable Magnus force on these sections. Rotation of these sections does, however, produce an appreciable Magnus force on the part of the body downstream of the maximum diameter. These results are believed to be associated with the position and strength of the vortices shed from the body. With the propeller on the body of revolution, a large Magnus force is developed on sections of the body behind the propeller. The Magnus force on sections ahead of the propeller is small and independent of whether these sections are rotating.

THEORETICAL CALCULATION OF THE FLOW ON BLUNT-NOSED AXISYMMETRIC BODIES IN A HYPERSONIC STREAM. M. Zlotnick and D. J. Newman. Avco, Res. & Advanced Devel. Div., RAD TR 2-57-29, Sept. 19, 1957. 68 pp. Development of both a rapid approximate calculation and a numerical method for obtaining a solution to any desired accuracy. The approximate method is developed for calculating stagnation-point velocity gradient, pressure distribution, and shock-detachment distance of the stagnation point on the face of a flat-nosed cylinder. A comparison of calculated stagnation-point shock distances with experimental results is shown to be satisfactory. The solution for the inverse problem of axisymmetric flow on a blunt body behind a given detached shock is presented, and some numerical results are shown.

STUDIES ON THE LOW SUPERSONIC FLOW WITH A DETACHED SHOCK; AN ANALYTIC DETERMINATION OF THE FLOW AROUND A CYLINDER WITH A DETACHED CURVED SHOCK. Jiro Kondo. Japan Soc. Aero. Eng. J., Sept., 1957, pp. 241-245. In Japanese. Analysis in which the stream function of the flow pattern behind the shock is expressed in a trigonometric series with undetermined coefficients. Then, assuming the shape and the location of the shock wave, linear equations of these coefficients are introduced by shock conditions. An example of flow at Mach 2 around a cylinder is worked out with a three-parameter approximation, and the density variation along the axis is compared with data obtained by experiment.

THE INTERACTION OF A REFLECTED SHOCK WAVE WITH THE BOUNDARY LAYER IN A SHOCK TUBE. Appendix I - MACH NUMBER DISTRIBUTION ACROSS THE BOUNDARY LAYER. Appendix II - A WEAK SHOCK REFLECTED AT A WALL. Appendix III - CALCULATION OF ANGLES OF THE INTERACTION PATTERN. Appendix IV - REYNOLDS NUMBER FOR THE REFLECTED SHOCK-BOUNDARY LAYER INTERACTION. Appendix V - CALCULATION OF THE SIZE OF THE SHOCK WAVE-BOUNDARY LAYER INTERACTION. Herman Mark. Cornell U. Grad. Sch. Aero. Eng. Rep. (AFOSR TN 57-345) [AD 132418], June, 1957. 149 pp. 20 refs. Analysis in which simplifying assumptions are made for the interaction of the shock reflected from the closed end of a shock tube with the boundary layer of the initial-shock afterflow. It is predicted that interactions of several different types will exist in different ranges of initial shock Mach Number, and it is shown that the cooling effect of the wall on the afterflow boundary layer accounts for the change in interaction type. An experiment verifies the existence of several interaction regions and shows that they are satisfactorily predicted by theory.

ON THE PROPAGATION AND DECAY OF SPHERICAL BLAST WAVES. T. Y. Thomas. J. Math. & Mech., Sept., 1957, pp. 607-619. Results of the application of recently obtained data on compatibility conditions to the problem of the propagation of spherical blast waves. It is assumed that the gas is devoid of viscosity and thermal conductivity; since the flow is spherically symmetric it is therefore governed by the equations of motion and continuity, and by the entropy condition. The problem is concerned with a spherical region, having its center at the point O, which is expanding into a gas at rest.

A RAPID METHOD FOR PREDICTING ATTACHED-SHOCK SHAPE. E. S. Love and R. H. Long. US, NACA TN 4167, Oct., 1957. 34 pp. Development of a method for the rapid prediction of the shape of attached shocks emanating from smoothly contoured axisymmetric and two-dimensional nose shapes. The method covers Mach Numbers from about 1.5 to 5.0 and semiapex angles at the tip of the nose up to values near those for sonic conditions behind the shock. From a practical viewpoint the accuracy of the method is comparable to that of the method of characteristics.

O SPINOVOI DETONATSII. B. V. Voitsekhovskii. AN SSSR Dokl., June 1, 1957, pp. 717-720. In Russian. Study of the spin detonation. The parameters of a gas in the space between the front of a shock wave and the combustion zone are determined by the upper bounds of the Hugoniot's adiabatic curve. An assumption is introduced stating that the Zhuge condition is valid for the entire spin detonation wave as well as for the secondary detonation wave, moving along the compressed gas behind the shock front perpendicular to the periphery.

MOLECULAR APPROACH TO PROBLEMS OF HIGH-ALTITUDE, HIGH-SPEED FLIGHT. G. N. Patterson. UTIA Rev. 10 (AFOSR TN 57-311) [AD 132382], May, 1957. 65 pp. 61 refs. Discussion of the zones in the upper atmosphere, the regimes of fluid mechanics based on considerations of rarefaction and temperature, and the modern experimental methods for investigations in some of these regimes. Further consideration is given to rarefaction effects (discussed in terms of gas-surface interactions), free molecule flow and slip flow, and Newtonian flow as an extension of free molecule motion. The effects of high temperature are indicated for undissociated air and air in dissociation equilibrium, and the important effects of relaxation are outlined.

INTRINSIC FORM OF THE CHARACTERISTIC RELATIONS IN THE STEADY SUPERSONIC FLOW OF A COMPRESSIBLE FLUID. N. Coburn. Quart. Appl. Math., Oct., 1957, pp. 237-248. OOR-supported expression of the characteristic relations for the steady, supersonic, three-dimensional, rotational and irrotational motion of a polytropic gas in intrinsic form, and application of these relations to the study of a class of space Beltrami motions. To obtain intrinsic forms of the characteristic relations, the equations of motion, continuity, and energy are expressed in terms of a set of characteristic variables. These variables are then reduced to intrinsic form by expressing the partial derivatives of the components of the velocity vector in terms of the directional derivatives for the magnitude of the velocity vector, q, the sound speed, c, and for the curvature vectors associated with the characteristic manifolds.

DIFFUSION IN FREE TURBULENT SHEAR FLOWS. G. K. Batchelor. J. Fluid Mech., Oct., 1957, pp. 67-80. Study of some statistical properties of the displacement of a marked fluid particle released from a given position in a turbulent shear flow, and in particular with the dispersion about the mean position after a long time. The analysis is based on the hypothesis that in steady free turbulent shear flows, which are generated at a point and have a similar structure at different stations downstream, the velocity of a fluid particle exhibits a corresponding Lagrangian similarity and can be transformed to a stationary random function.

FURTHER INVESTIGATIONS ON THE TRIANGULAR-PATCH STIMULATOR. J. C. Hegarty and F. R. Hama. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-107 (AFOSR TN 57-616) [AD 136605], June, 1957. 10 pp. Investigation into the effect the geometry of triangular patches has in causing breakdown from laminar to turbulent flow. Results indicate that variations in shape and size of the plan form of the triangles do not affect the transition Reynolds Number appreciably. The effectiveness, however, is rather sensitive to the flow direction to the stimulator.

EQUIPARTITION OF ENERGY AND LOCAL ISOTROPY IN TURBULENT FLOW. M. S. Uberoi. J. Appl. Phys., Oct., 1957, pp. 1,165-1,170. Investigation of homogeneous turbulence in which $\langle v^2 \rangle = \langle w^2 \rangle \neq \langle u^2 \rangle$ is produced experimentally, where $\langle u^2 \rangle$, $\langle v^2 \rangle$ and $\langle w^2 \rangle$ are the mean-square turbulent velocities in x, y, and z direction, re-

spectively. The decay of turbulence and the energy transfer between $\langle u^2 \rangle$ and $(\langle v^2 \rangle + \langle w^2 \rangle)$ are measured, and its is found that the larger components ($\langle v^2 \rangle$ and $\langle w^2 \rangle$) are losing more energy due to viscosity than by transfer to the smaller component ($\langle u^2 \rangle$). However, $\langle u^2 \rangle$ is receiving enough energy by transfer to compensate for its decay and is in fact slowly increasing. The measurement of mean-square vorticity components shows that the turbulence is becoming locally isotropic at a faster rate than the equipartition of energy is taking place. In another set of experiments it is found that when isotropic turbulence is subjected to deformation, the three components of turbulent energy become widely different in magnitude and that the turbulence is not locally isotropic. This indicates that even at high Reynolds Number the deformation in a shear flow may cause anisotropy.

Internal Flow

AEROFOILS IN CASCADE WITH BOUNDARY LAYER CONTROL. C. H. J. Johnson. Australia, ARL Mech. Eng. Note 222, July, 1957. 9 pp. Design of a cascade determined on the basis of its velocity distribution in two-dimensional flow. The method of design is due to Lighthill and involves prescribing the velocity over the two-dimensional airfoil surface as a function of position on the unit circle into which the cascade of airfoils is transformed. The principal featuer of the present cascade design is the inclusion in the velocity distribution of a steep fall in velocity toward the trailing edge over a short distance on the upper surface of each airfoil. This steep fall is made possible by the action of a "suction area."

SOME REMARKS ON THE SOLUTION OF A SYSTEM OF EQUATIONS OCCURRING IN LAMINAR MIXING WITH AXIAL PRESSURE GRADIENTS. L. G. Napolitano. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 393 (AFOSR TN 57-609) [AD 136599], Sept., 1957. 15 pp. Investigation of a fifth order system of equations with three-point boundary conditions in order to obtain solutions by means of high speed computing machine. Two methods of solution are presented. In the first one a suitable change of variables reduces the original equations to integro-differential equations defined over a finite interval of the independent variable. The second method considers the solution as an "initial value" problem.

AN INVESTIGATION ON DIFFUSION IN A SUPERSONIC COMPRESSOR STATOR PASSAGE IN THE PRESENCE OF ROTOR BLADE WAKE AND HUB AND SHROUD BOUNDARY LAYER. V. D. Agosta and Anthony Martellucci. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech. PIBAL Rep. 394, Oct., 1957. 44 pp. 14 refs. ONR-sponsored experiments in which data are obtained for four wake positions, with respect to the stator passage inlet, and for two boundary layer thicknesses, on the hub and shroud surfaces. Throughout the investigation the stator passage is two-dimensional with no turning and consists of two blade surfaces and a hub and a shroud surface. Test results indicate that, for the supersonic diffuser, the losses due to nonhomogeneity are greater than those due to viscous mixing. Therefore, in order to obtain high pressure recovery, the distance between the wake generating source and the diffuser throat should allow diffusion of the wake.

AN INVESTIGATION OF FLOW IN CIRCULAR AND ANNULAR 90° BENDS WITH A TRANSITION IN CROSS SECTION. S. W. Wilbur. US, NACA TN 3995, Aug., 1957. 32 pp. Study of the performance of circular and annular 90° bends with cross-sectional areas that are constant, expanding, and contracting. The data presented include the exit velocity profiles, the relative total-pressure loss coefficients measured at the exit station, and an index for the exit total-pressure distortion. Separation of the flow in the bend occurs for all configurations except those of contracting area. With the transition in cross section downstream of the bend proper, the separated region is removed by natural mixing but is accompanied by higher pressure losses.

ON THE INFLUENCE OF WALL BOUNDARY LAYERS IN CLOSED TRANSONIC TEST SECTIONS. Appendix I, II - UNIQUENESS THEOREMS. Appendix III - AN APPROXIMATE BOUNDARY CONDITION FOR SUPERSONIC FLOW. S. B. Berndt. Sweden, Flygtekniska Försöksanstalten, FFA Medd. 71 (Rep. 71), 1957. 78 pp. 38 refs. Application of the small perturbation theory to study the effect of boundary layers on reduction of wall interference at the test section walls of a transonic wind tunnel. It is assumed that viscosity is negligible when perturbating the layer. An approximation for thin boundary layers leads to a modified boundary condition at the wall of the test section, expressing the normal streamline slope induced by changes in mass flow density and cross flow within the boundary layer. Application of this boundary condition to the linearized equations of subsonic flow and to the non-linear transonic equations at choking indicates that all corrections, except the three-dimensional angle-of-attack correction, are considerably reduced by the presence of the boundary layers at Mach Numbers greater than 0.9.

TWO DIMENSIONAL COMPRESSIBLE SHEAR FLOW IN A CHANNEL. J. D. Murray. Quart. Appl. Math., Oct., 1957, pp. 231-236. Illustration of the principal physical features of the completely sub- and supersonic adiabatic rotational flow through a divergent channel, with particular reference to the effect of the divergence of the channel on the vorticity and the stream lines.

A NOTE ON TURBULENT BOUNDARY-LAYER ALLOWANCES IN SUPERSONIC NOZZLE DESIGN. E. W. E. Rogers and B. M. Davis. Gt. Brit., ARC CP 333, 1957. 24 pp. 32 refs. BIS, New York, $0.54. Discussion of theoretical methods for computing the growth of turbulent boundary layers along both the curved and straight walls of a rectangular supersonic wind tunnel. Comparison of estimated values with those obtained through ex-

perimentation indicates that there is slight evidence for the assertion sometimes made that transition occurs on the curved contour at the point of inflection downstream of the throat. Since the transition position fluctuates with tunnel stagnation pressure, and because the boundary layer growth near the transition region is not easy to calculate, it may be desirable to provoke transition artificially (by means of a wire or surface roughness, for example) well upstream of the throat.

VISCOUS FLOWS PAST A SPHEROID. Shōichi Wakiya. Phys. Soc. Japan J., Oct., 1957, pp. 1,130-1,141. Solutions of Stokes equations for flows past an ellipsoid. Utilizing these results, two kinds of steady flows past a spheroid are studied when the direction of the main stream is parallel to the axis of symmetry of the spheroid. The first is the flow past a spheroid between two parallel walls, and the second is the flow past a spheroid in a cylindrical pipe. The drag and moment acting on the spheroid as well as the pressure drop in the pipe are discussed.

STATIC PRESSURE DISTRIBUTION IN THE FREE TURBULENT JET. D. R. Miller and E. W. Comings. J. Fluid Mech., Oct., 1957, pp. 1-16. 22 refs. Measurements of mean velocity, turbulent stress, and static pressure in the mixing region of a jet of air issuing from a slot nozzle into still air. The results are examined in terms of the unsimplified equations of fluid motion, and comparisons are drawn with the common assumptions and simplifications of free jet theory. Appreciable deviations from isobaric conditions exist, and the deviations are closely related to the local turbulent stresses. Negative static pressures are encountered everywhere in the mixing field except in the potential wedge region immediately adjacent to the nozzle. Lateral profiles of mean longitudinal velocity conform closely to an error curve at all stations further than seven slot widths from the nozzle mouth.

A PHILOSOPHY FOR IMPROVED ROCKET NOZZLE DESIGN. R. B. Dillaway. Jet Propulsion, Oct., 1957, pp. 1,088-1,093. 16 refs. Method to design short high area ratio supersonic nozzles having performance equal to or superior to present conical nozzle motors at design altitude. The assumptions and approximations used are presented together with the procedure for applying the characteristic method of flow analysis in the nozzle in arriving at a proper nozzle wall contour for axial exhaust.

THE LAMINAR AND TURBULENT MIXING OF JETS OF COMPRESSIBLE FLUID. II - THE MIXING OF TWO SEMI-INFINITE STREAMS. L. J. Crane. J. Fluid Mech., Oct., 1957, pp. 81-92. Application of methods developed in a previous paper to the mixing of two parallel streams for both laminar and turbulent flows. The effects of high velocity and large temperature difference are treated together. The stream function is developed in a double series of powers for two parameters, the first being the Mach Number and the second depending on the temperature difference of the streams.

Stability & Control

THE ROLL COUPLING PROBLEM - A MATHEMATICAL APPROACH. R. Westerwick. Aero. Eng. Rev., Dec., 1957, pp. 48-51. Analysis using linearized equations of motion and the predominant cross-coupling terms. The equations are divided into two sets: the steady-state equations and the stability equations. The solutions are made in terms of the Laplace operator S. If any root is positive, the aircraft is unstable at the rolling rate ϕ_o. The type of automatic control to correct inertia coupling is determined. This involves the decrease in pitching moment coefficient, or the increase in the rolling moment coefficient.

Wings & Airfoils

ULTRASCHALLWELLE AM TRAGFLÜGEL-PROFIL BEI HOHLSOG. I. F. Numachi. Tōhoku U., Rep. Inst. High Speed Mech., vol. 8, 1957, pp. 141-162. In German. Experimental investigation of the ultrasonic wave spectra produced by cavitation, using Clark Y airfoil profiles. The relationship between the wave frequency and the shock pressure at various angles of incidence depending on the cavitation number is also studied.

TRANSONIC FLOWS AROUND SYMMETRIC AIRFOILS, WITH DETACHED SHOCK WAVE. Silvio Nocilla. Torino Polytech. Inst. Appl. Mech. Lab. TN 1 (AFOSR TN 57-493) [AD 136483], Apr. 24, 1957. 27 pp. Extension of the approximation of Tomotika and Tamada to the development of a process for constructing motion fields around symmetrical wing profiles. As a basis for the work, suitable singular functions on the hodograph plane are utilized as stream functions, and the asymptotic Mach Number is taken as greater than one. The theoretical setting-up is followed by the numerical calculation of a particular profile and the flow around it, as well as by a comparison with the corresponding results relating to the case in which the Mach Number equals one.

THE USE OF PURE TWIST FOR DRAG REDUCTION ON ARROW WINGS WITH SUBSONIC LEADING EDGES. Appendix A - GENERAL FORMULAS FOR PRESSURE DISTRIBUTIONS. Appendix B - CALCULATION OF LEADING-EDGE THRUST. F. C. Grant. US, NACA TN 4104, Aug., 1957. 28 pp. Linearized-theory calculations to determine the drag reduction achieved by applying the first three terms of a power series for twist to flat delta wings, and the drag reduction achieved by applying linear delta twist to a family of flat arrow wings. Results show a 6% drag reduction in twisting for a flat delta wing with sonic leading edges, and a steady decrease in the gains as sweepback increases. For a family of linearly twisted arrow wings, the maximum drag reduction is 2% in the medium sweepback range with a steady diminution in both directions.

THE BODY LIFT OF LOW ASPECT RATIO WING-BODY COMBINATIONS IN STEADY SUBSONIC FLOW. Fu-Hsing Tsien. Japan Soc. Aero. Eng. J., Sept., 1957, pp. 246-250. In Japanese. Calculation using the lifting surface theory and the weighting function of complex potential for slender wing-body combinations. The result is compared with Spreiter's theory for the body lift of very low aspect ratio wing-body combinations, and with other theories obtained from lifting line theory for high aspect ratio wing-body combination. It is found that the result is valid over the whole range of the body diameter-to-span ratio. The method is shown to be a better approximation than the above theories over a range of aspect ratios from zero to four.

AEROELASTICITY

FLUTTER OF WINGS WITH LOCALISED MASSES. W. G. Molyneux. RAeS J., Oct., 1957, pp. 667-678. 19 refs. Deductions indicating that there is an optimum choice of modes for use in flutter calculations for wings with localized masses. These modes are obtained with artificial constraints imposed on the wing at the localized mass section fixing the wing at this section in translation and/or pitch. It is deduced that for certain mass locations, types of flutter are obtained that are insensitive to increase of localized mass, beyond a certain value, with flutter speeds considerably greater than that of the fixed root bare wing. It is further concluded that, for the majority of aircraft configurations, the maximum flutter speeds for these types of flutter will be realized when the localized mass is in the region of two-thirds semi-span from the root.

EFFECTS OF AIRPLANE FLEXIBILITY ON WING STRAINS IN ROUGH AIR AT 5,000 FEET AS DETERMINED BY FLIGHT TESTS OF A LARGE SWEPT-WING AIRPLANE. R. H. Rhyne and H. N. Murrow. US, NACA TN 4107, Sept., 1957. 32 pp. Includes determination of amplification factors defining the ratio of the strains in rough air to the strains expected for a rigid and quasi-rigid airplane. The latter investigation is carried out in order to evaluate the overall magnitude of the aeroelastic effects on the strains and their variation with spanwise location, and the results indicate that such effects are rather large, particularly at the outboard stations. The effects of dynamic aeroelasticity appear to increase the strains from 0 to 170%, depending on the spanwise station; on the other hand, the relieving effects of static aeroelasticity appear to reduce the strain amplification in rough air by a significant amount.

ESTIMATION OF THE FREQUENCIES OF THIN ELASTIC PLATES WITH FREE EDGES. Tosio Kato, Hiroshi Fujita, Yoshimoto Nakata, and Morris Newman. J. Res., Sept., 1957, pp. 169-186. 11 refs. Consideration of a variational method of calculation with rigorous error estimates. As a numerical example, the fundamental frequency of a square plate with the Poisson ratio 0.225 is calculated with a satisfactory result, the possible relative error being less than 1/2000. Generalization to more complicated boundary conditions is straightforward.

INSTRUMENTS

Flow Measuring Devices

MICRODEBITMETRE A PERTE DE CHARGE D.F.G. F. Debeauvais, R. Feidt, and C. Gebel. France, Min. de l'Air NT 64, 1957. 23 pp. 12 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 400. In French. Description of the D.F.G. pressure loss microflowmeter intended for measuring flow quantities of the order of cc./sec. This instrument uses the principle of the loss of pressure, in laminar regime, of a liquid in a long capillary tube, of linear pressure/flow characteristics. The developed theory takes into account entry corrections and temperature effects. Includes description of experimental investigations and calibration.

MATERIALS

Metals & Alloys

CONTROLE DE LA QUALITE DES MATERIAUX METALLIQUES DESTINES A LA CONSTRUCTION DES MOTEURS D'AVION. R. Huet de la Tour. Docaéro, Sept., 1957, pp. 51-60. In French. Discussion of the control over the metals and their alloys used for aircraft construction. Includes: determination of properties, chemical and metallurgical criteria, effect of homogeneity; various defects and methods for their detection; production techniques; design techniques; creation of a central agency and development of means of control.

MATERIALS FOR AIRCRAFT STRUCTURES SUBJECTED TO KINETIC HEATING. A. J. Murphy. RAeS J., Oct., 1957, pp. 653-666. Discussion of alloys of aluminum, magnesium, titanium, and nickel, and of steel, in relation to their suitability for structures operating at speeds of up to Mach Number 4 with accompanying temperatures of up to 400°C. Test results indicate that there will be technical competition between the stronger heat-treated titanium alloys and precipitation-hardened stainless steels. The steels have an important advantage in their greater case of working when in the "solution-treated" condition. In cases where a low coefficient of thermal expansion combined with high strength is of major importance, consideration might be given to the precipitation-hardening Invars.

MATHEMATICS

COHOMOLOGY OPERATIONS AND OBSTRUCTIONS TO EXTENDING CONTINUOUS FUNCTIONS. N. E. Steenrod. Princeton U. Colloquium Lectures (AFOSR TN 57-548) [AD 136532], Aug., 1957. 60 pp. 30 refs. Discussion of the current stage of development of algebraic topology, with emphasis upon investigations undertaken in the hope of finding a general solution to the many extension problems remaining unsolved. After general outlines of the extension problem and the methods of finding solutions in special cases, a review is

presented of the research done by Eilenberg-MacLane, H. Cartan, and others, and the conclusion states the possibility that what is needed is a method of dissecting a mapping similar to the dissection of spaces.

THE PADE TABLE AND THE τ-METHOD. Y. L. Luke. Midwest Res. Inst. Rep. (AFOSR TN 57-570) [AD 136555], Aug., 1957. 42 pp. 24 refs. Study of required analytic tools to appraise the error incurred when approximating a given transcendental with a given number of terms. To do this the rational function representations of the function E are presented. Closed form expressions for the error are derived, and it is shown that these may be used to realistically appraise the error in a convenient manner.

ON THE NUMERICAL SOLUTION OF STURM-LIOUVILLE DIFFERENTIAL EQUATIONS. C. C. Farrington, R. T. Gregory, and A. H. Taub. Math. Tables & Aids to Comp., July, 1957, pp. 131-150. Analysis to obtain an algebraic characteristic-value problem from whose solution approximations may be derived to the characteristic values and characteristic functions of the Sturm-Liouville equation. Treatment makes use of the well-known relation existing between a Sturm-Liouville differential equation - together with its boundary conditions and normalization condition - and a problem in the calculus of variations.

MISSILES

A STUDY OF THE MOTION AND AERODYNAMIC HEATING OF MISSILES ENTERING THE EARTH'S ATMOSPHERE AT HIGH SUPERSONIC SPEEDS. Appendix A, B - SIMPLIFYING ASSUMPTIONS IN THE CALCULATION OF AERODYNAMIC HEATING. H. J. Allen and A. J. Eggers, Jr. US, NACA TN 4047, Oct., 1957. 61 pp. 16 refs. Simplified analysis of the velocity and deceleration history of missiles entering the earth's atmosphere at high supersonic speeds. The results of this motion analysis are used to indicate means available to the designer for minimizing aerodynamic heating. The heating problem considered involves not only the total heat transferred to a missile by convection, but also the maximum average and local time rates of convective heat transfer.

EXIT AND RE-ENTRY PROBLEMS. G. V. Bull, K. R. Enkenhus, and G. H. Tidy. CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 759. 11 pp. 21 refs. Members, $0.35; nonmembers, $0.75. Review of some of the problems associated with the exit and re-entry portions of long range ballistic rocket trajectories. Initial consideration is given to the nature of typical ballistic trajectories in order to establish the range of values of pertinent parameters. After reviewing the various phases of some of the flight problems associated with the range of parameters indicated, some of the current laboratory simulation equipment is discussed. Discussions are confined to the extreme hypersonic Mach Number problems.

MOTION OF A BALLISTIC MISSILE ANGULARLY MISALIGNED WITH THE FLIGHT PATH UPON ENTERING THE ATMOSPHERE AND ITS EFFECT UPON AERODYNAMIC HEATING, AERODYNAMIC LOADS, AND MISS DISTANCE. Appendix A, B - DETERMINATION OF ANGULAR VELOCITY AND ANGULAR ACCELERATION. Appendix C - NUMERICAL INTEGRATION METHOD FOR THE INTEGRAL F (k_0, k_1, k_2). Appendix D - ORDER OF MAGNITUDE OF FACTORS AFFECTING STABILITY. H. J. Allen. US, NACA TN 4048, Oct., 1957. 66 pp. 10 refs. Analysis of the oscillating motion of a ballistic missile and discussion of the history of motion for some example missiles. The miss distance at the target due to misalignment and to small accidental trim angles is treated. The stability problem is also discussed for the case where the missile is tumbling prior to atmospheric entry.

A COMPARATIVE ANALYSIS OF THE PERFORMANCE OF LONG-RANGE HYPERVELOCITY VEHICLES. Appendix A, B - SIMPLIFYING ASSUMPTIONS IN THE ANALYSIS OF THE GLIDE TRAJECTORY. Appendix C, D - COMPUTATION OF HEATING ASSOCIATED WITH ROCKET VEHICLES. Appendix E - DETERMINATION OF THE RATIO OF $(L/D)_{max}$ FOR A FLAT PLATE TO $(L/D)_{max}$ FOR A CONE. A. J. Eggers, Jr., H. J. Allen, and S. E. Neice. US, NACA TN 4046, Oct., 1957. 66 pp. 13 refs. Studies of long-range hypervelocity ballistic, glide, and skip missiles in terms of motion in powered flight, and motion and aerodynamic heating in unpowered flight. Results indicate the ballistic vehicle to be the least efficient of the types tested; the glide vehicle to be far superior to the ballistic vehicle in ability to convert velocity into range; and the skip vehicle to be supperior to both. On the basis of equal ratios of mass at take-off to mass at the end of powered flight, the hypervelocity vehicle compares favorably with the supersonic airplane for ranges in the neighborhood of and greater than one half the circumference of the earth. It is concluded that ballistic and glide vehicles have, in addition to the advantages usually ascribed to great speed, the possibility of providing relatively efficient long-range flight.

ON THE EQUATION OF ROCKET MOTION. G. Leitmann. Brit. Interpl. Soc. J., July-Sept., 1957, pp. 141-147. Derivation of the momentum of a time-variant mass, which in turn is used to derive the equations of motion. It is shown that the burn-out velocity of a rocket in field-free vacuum is dependent on the mass flow rate. The resultant expressions are contrasted with those arising from classical derivation.

ASPECTS OF HIGH ENERGY BALLISTICS. Louis Gold. Franklin Inst. J., Oct., 1957, pp. 301-311. Development of the dynamics of motion appropriate in the supersonic velocity region where satellite orbits can exist or, possibly, escape from a gravitational field. A more realistic treatment of the falling body problem is offered which leads to vertical flight relations that clearly indicate

transition from bound to free states of motion. The results of celestial mechanics are adapted and extended toward a broader appreciation of high-energy ballistics.

PHYSICS

ON THE DISSOCIATION RATE OF A DIATOMIC GAS. Gianny Jarre. Torino Polytech. Inst. Appl. Mech. Lab. TN 2 (AFOSR TN 57-528) [AD 136513], July 25, 1957. 12 pp. 12 refs. Derivation of a formula of the reaction rate, for use in studies on hypersonic flow of diatomic gases. The formula is derived from the theory of absolute reaction rate, which postulates the existence of an intermediate state between the molecule and the two atoms, called the "activated complex". Its properties determine the reaction rate. Indirect experimental information describes the "activated complex" of the reaction as an ensemble of two atoms already dissociated but in a state still possessing the entropy of the molecule.

THE PLASMA JET AND ITS APPLICATION. G. M. Giannini. Giannini Res. Lab. Rep. (AFOSR TN 57-520) [AD 136505], Aug 2, 1957. 30 pp. Discussion of the physical principles of a plasma jet, and the methods to create this phenomenon. With such a jet, temperatures of over 5,000° K. are possible. Applications are presented for the machining of a refractory metal or ceramics, and to the possibility of fusing highly refractory materials. The study of magnetohydrodynamics and the natural fusion of the stars is also discussed.

MEASUREMENT OF AIR DENSITY BY ELECTRON ABSORPTION. A. E. Grün. Max-Planck Inst. für Phys. Stratosphäre, Hochspannungslab. Hechingen FTR (AFOSR TR 57-58) [AD 136515], 1957. 9 pp. Application of measurements of the energy absorption of air in the radiation field of a specially constructed electron source to the measurement of the air density. The main features of the measuring arrangement are a specially constructed electron source and a light detecting system which receives the luminescence radiation of the air excited by the electrons. The range of densities that can be measured extends from normal density ρ_o down to $10^{-2}\ \rho_o$ and is determined by the range of acceleration voltages with which the electron source can be operated.

POWER PLANTS

Jet & Turbine

GAS TURBINE COMBUSTION SYSTEM DESIGN. F. D. M. Williams. CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 754. 15 pp. Members, $0.50; nonmembers, $0.85. Discussion of the design rules and simple analytical approach employed in the process of evolving and evaluating a combustion system design for a specific project, such as an advanced type of jet engine. Design parameters are presented and application is made to an annular vaporizing combustion system. Flame intensities are determined in conjuction with a flow analysis, and are used to outline the flame tube geometry. Ignition system selection and development is discussed along with mechanical reliability problems.

RECENT ADVANCES IN THE AERODYNAMIC DESIGN OF AXIAL TURBOMACHINERY. W. H. Robbins and H. W. Plohr. CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 762. 28 pp. Members, $0.35; nonmembers, $0.75. Discussion of three primary objectives of compressor or turbine design: (1) high airflow per unit frontal area, (2) high pressure ratio per compressor stage and high work output per turbine stage, (3) high efficiency. These goals can be achieved by proper selection of Mach Number and blade loading operating levels. For the compressor the range of rotor tip Mach Numbers over which high efficiency can be maintained has been extended to values above one. This results in gains of weight flow per unit of frontal area and in pressure ratio per stage over those of conventional subsonic compressors.

DUAL-OPERATION POWERPLANTS FOR VERTICAL TAKE-OFF TRANSPORT AIRCRAFT: A PRELIMINARY ANALYSIS OF SEVERAL GAS-TURBINE CYCLES. Appendix - PERFORMANCE CURVES. E. P. Cockshutt. Canada, NAE LR 201, July 30, 1957. 19 pp. Presentation of calculations for (a) a hot single-stream cycle, which appears to offer the best over-all thermodynamic performance if no limit is placed on the interconnecting duct temperature; (b) a mixed-stream cycle, apparently offering better performance at lower duct temperatures (less than 500°C); (c) a dual-stream cycle, for achievement at very low duct temperatures (less than 200°C); and (d) tipjet drives, which may be used in place of conventional power turbines to drive the thrust augmentors, but are more suited for large rotors of low disc loading.

Ram-Jet & Pulse-Jet

APPLICAZIONE DELLA TEORIA DELLA CORRENTE UNIDIMENSIONALE ALLO STUDIO DEL MOTO NON STAZIONARIO DEL FLUIDO IN PULSOGETTI RUOTANTI. Dino Dini. L'Aerotecnica, June, 1957, pp. 107-128. 12 refs. In Italian. Analysis of a particular rotating pulse-jet tube performing a controlled cycle in which the entering charge consists partially of a stoichiometric mixture and partially of fresh air. The pressure and velocity-wave diagram of the flow in the tube is investigated under different conditions. For the first approach to the problem, it is assumed that the fluid is homogeneous and at constant entropy level. For a better approach to the actual conditions, it is assumed that the fluid involved in combustion and the fluid taking part in the propulsive phenomenon have different entropy levels. Operations of a rotating pulse-jet are deduced, taking into account the possible combustion behavior on the wave diagram; cycle frequencies are deduced in reasonable agreement with experimental measurements on conventional pulse-jets.

Rocket

A SANDWICH BURNER MODEL FOR THE COMPOSITE SOLID PROPELLANT. W. Nachbar and

J. M. Parks. Lockheed Aircraft LMSD-2191 (AFOSR TN 57-418) [AD 132497], Sept. 25, 1957. 39 pp. Consideration of an idealized solid propellant sandwich burner, composed of alternating flat slabs of fuel and oxidizer which are ignited edgewise, for theoretical study of the functional relationship of the regression rate, pressure, and surface temperature in the combustion of composite solid propellants. This relationship is also studied with respect to its dependence on geometry and on physical and chemical material properties. The work of Powell on the gaseous sandwich burner is reviewed in detail to clarify the assumptions and certain mathematical procedures used

SPACE TRAVEL

SKIN TEMPERATURES OF A SATELLITE. C. M. Schmidt and A. J. Hanawalt. Jet Propulsion, Oct., 1957, pp. 1,079-1,083. Analysis of temperatures that exist on a particular satellite configuration and to study the various pertinent parameters in order to determine their relative importance. The skin temperatures are dependent on the properties of the surface, particularly emissivity and absorptivity, large values producing the widest range in surface temperatures. The nominal limits, on the skin temperatures for this analysis are -200° and +400°F.

TRANSFER BETWEEN VEHICLES IN CIRCULAR ORBITS. B. H. Paiewonsky. USAF WADC TN 57-267 [AD 130916], Aug., 1957. 9 pp. Development of a method for calculating the initial angular separation between two vehicles in circular orbits, required for the orbital transfer of a commuter rocket with a minimum expenditure of fuel. The time of flight in the orbit of transfer is used to compute the required vehicle relationships from their orbital angular velocities. The orbits of transfer between circular orbits are Hohmann orbits (cotangential ellipses). A method is also presented for determining the relative angular positions of the satellites from in-flight measurements for the case of unobscured line of sight between satellites.

ORBITAL BEHAVIOR OF ERATH SATELLITES. II - ORBITS ABOUT AN OBLATE SPHEROID. R. E. Roberson. Franklin Inst. J., Oct., 1957, pp. 269-285. Presentation of a method to (1) deduce the orbit geometry in the field of an oblate spheroid, as if no other external forces act; (2) calculate a rotating reference frame with respect to which the orbit is periodic; (3) relate the elements of the orbit to the kinematic and geometric initial conditions which exist when the orbit is established; and (4) develop the time behavior of the basic dependent variables which describe the orbit. The principal limitation of the analysis is its restriction to first order effects in the oblateness parameter.

STRUCTURES

THE USE OF SEMI-ORTHOGONAL FUNCTIONS IN THE RALEIGH-RITZ METHOD OF SOLVING PLANE STRESS PROBLEMS. F. E. Archer and E. M. Kitchen. Australian J. Appl. Sci., Sept., 1957, pp. 169-179. Examination of orthogonal and semi-orthogonal functions in order to reduce the necessary computations. Avoiding the use of simultaneous equations, an example of plane stress is used to explain a method of determining the parameters.

HANDBOOK OF STRUCTURAL STABILITY. IV - FAILURE OF PLATES AND COMPOSITE ELEMENTS. V - COMPRESSIVE STRENGTH OF FLAT STIFFENED PANELS. George Gerard. US, NACA TN 3784; TN 3785, Aug., 1957. 93; 89 pp. 75 refs. Review of available theories on failure of flat panels, and of test data on the crippling strength of various formed and extruded shapes. From this a generalized method of crippling analysis is formulated, which is extended for short monolithic panels with formed or extruded stiffeners. The effects upon the crippling strength of alclad coatings and the increased properties in the corners of formed sections are investigated. It is found that the crippling of all sections is governed in a simple manner by the developed length-thickness ratio and by the number of corners of the section. Intermediate length and long stiffened panels are subject to other failure modes, and methods are given for estimating the column strength of these panels.

THE TORSION OF A HOLLOW SQUARE. J. L. Synge and W. F. Cahill. Quart. Appl. Math., Oct., 1957, pp. 217-224. OSR-supported utilization of the Standards Eastern Automatic Computer to give an approximate solution to the torsion problem for a hollow square. The upper and lower bounds for torsional rigidity are accurately determined.

THE SAFETY OF AIRCRAFT STRUCTURES. A. M. Freudenthal. USAF WADC TR 57-131 [AD 130910], July, 1957. 37 pp. Analysis of the concept of structural safety of airframes on the basis of its relation to the probability of structural failure, with a view of establishing procedures of quantitative evaluation of safety factors for a predetermined "acceptable" risk of failure. The difference in the approach to the concept of safety for ultimate strength and for fatigue is discussed, with emphasis on the results of fatigue tests under random loading, and methods of safety analysis for both conditions are proposed. In this analysis the "limit load" or "limit load factor" is a basic concept.

Beams & Columns

THE EFFECTS OF INELASTIC ACTION ON THE RESISTANCE TO VARIOUS TYPES OF LOADS OF DUCTILE MEMBERS MADE FROM VARIOUS CLASSES OF METALS. III - THE PLASTIC BENDING OF TAPERED MEMBERS. Appendix - THE DEFORMATION OF PLANE SECTIONS IN A TAPERED BEAM. M. C. Steele and H. A. Hassan. USAF WADC TR 56-330, Pt. III [AD 130865], June, 1957. 32 pp. Exploratory investigation employing two analytical approaches. The first considers a rigorous treatment by the classical theories of elasticity and plasticity, while the second resorts to the more tractable mechanics of materials methods. Test results indicate that (1) in the elastic range, deflections are adequately described by

elasticity theory; (2) fully plastic or limit loads have the same value for both theoretical approaches; (3) deflections in the elastic-plastic member are not represented adequately by the mechanics of materials solution; and (4) test beams show the existence of a pronounced upper yield point phenomenon.

Cylinders & Shells

NONAXIALLY SYMMETRIC MOTIONS OF CYLINDRICAL SHELLS. I. Mirsky and G. Herrmann. ASA J., Oct., 1957, pp. 1,116-1,123. OSR-supported application of Timoshenko-type theory of cylindrical shells, developed previously by the authors for the case of axial symmetry, to include nonaxially symmetric motions. The propagation of free harmonic waves in the axial direction of a shell of infinite extent is studied and discussed in terms of previous work. The stress equations of motion of the shell are derived by direct application of Hamilton's principle, rather than by operating on the three-dimensional equations of motion. Numerical calculations are performed for the full range of wavelengths, for three values of thickness to mean radius ratios, and for values of circumferential waves ranging from zero to six.

EDGE STRESSES IN THIN SHELLS OF REVOLUTION. W. H. Wittrick. Australia, ARL Rep. SM. 253, June, 1957. 34 pp. Analysis by which explicit solutions are obtained for stress system which decay rapidly with the distance from either a circular or a meridional edge of a thin shell whose shape is a surface revolution, but otherwise arbitrary. The accuracy of the solutions is consistent with that of the generally accepted equations of thin shell theory. The significance of these solutions from the point of view of the boundary conditions of membrane theory is discussed.

Elasticity & Plasticity

REFLECTION PRINCIPLES FOR SOLUTIONS OF EQUATIONS IN ELASTICITY. J. H. Bramble. U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-106 (AFOSR TN 57-499) [AD 136489], Aug. 1957. 59 pp. 34 refs. Presentation of certain reflection principles (analogous to the classical Schwarz reflection for harmonic functions) for biharmonic functions which arise as solutions of equations in elasticity. Formulas analogous to those given by Duffin for the plane boundary are proven for the circular boundary in the biharmonic case. In addition, the "sliding clamped" condition is also considered. Continuations for the solutions of equations of elasticity are given in the case where the displacements vanish on a circular arc or spherical surface in two or three dimensions, respectively. Also, in case the normal stresses vanish on a circular arc, a continuation formula for the stresses is obtained.

PLASTIC YIELDING OF NOTCHED STRIPS UNDER CONDITIONS OF PLANE STRESS. Hugh Ford and George Lianis. ZAMP, Sept. 25, 1957, pp. 360-382. Analysis of single notched strips subjected to bending in the plane of the sheet. Upper bounds are found for a single V- and circularly notched strips in bending, and the general lower bound solution is applied to both of these cases.

DETERMINATION OF BUCKLING CRITERIA BY MINIMIZATION OF TOTAL ENERGY. Samuel Lubkin. NYU Inst. Math. Sci. IMM-NYU 241 (AFOSR TN 57-579) [AD 136567], July, 1957. 60 pp. Derivation of formulas for strain energy in terms of principal strains, and development of exact buckling criteria from the effect of small perturbations (resulting from displacements in an unbuckled state) upon the total energy. When this method is then applied to three problems, results for thin sections agree, in all cases, with those derived by other means. It is then shown that with the given assumption, a buckling or critical load always exists, no matter what the geometric proportions. It is further shown that a finite pressure may expand the cylinder or sphere to infinity.

Plates

SMALL DEFLECTION THEORY OF FLAT PLATES USING COMPLEX VARIABLES. I - FUNDAMENTAL EQUATIONS IN COMPLEX FORM. P. D. Jones. Australia, ARL Rep. SM. 252, June, 1957. 22 pp. 23 refs. Application of Muskhelishvili's complex variables method to solutions for thin elastic plates. The boundary equations are set up in such a way as to lead to certain basic types of problems. Plates whose shapes are such that they can be mapped onto the unit circle by polynomial transformation functions are discussed, and the loading cases considered consist of continuously differentiable pressure distributions, point loads, line loads, and regional loads.

REINFORCED ELLIPTICAL HOLES IN STRESSED PLATES. Raymond Hicks. RAeS J., Oct., 1957, pp. 688-693. Consideration of stress systems in which the ratio of the principal stresses is not greater than two to one. It is shown that when the ratio of the major and minor axes of the ellipse can be chosen arbitrarily, practical reinforcements can be designed to give a maximum stress around the hole which is only slightly greater than the maximum stress in a similarly loaded plate with no hole. General expressions are obtained for the stress distribution in the plate around the hole, for the stress acting on a normal cross section of the reinforcement, and for the cross-sectional area of a reinforcement which gives a small stress concentration.

Thermal Stress

SOME EFFECTS OF KINETIC HEATING ON THE STIFFNESS OF THIN WINGS. S. L. Kochanski and J. H. Argyris. Aircraft Eng., Oct., 1957, pp. 310-318. 13 refs. Analysis (based on the small deflection theory) showing that the thermal stresses developed in accelerated flight lead also to a loss of flexural stiffness of equally serious magnitude. Included is an account of the loss of torsional stiffness, as well as a re-examination of the problem from the point of view of the large deflection theo-

ry. Possible methods of alleviating the effects of kinetic heating are also briefly discussed.

SOLUTIONS OF SOME PROBLEMS IN STEADY CREEP. B. Venkatraman. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 402 (AFOSR TN 57-388) [AD 132463], July, 1957. 120 pp. 41 refs. Analysis in which the deformations are caused exclusively by steady creep. The particular problems considered are trusses, beams and frames, a thick-walled tube subject to uniform internal pressure, pure torsion of prismatic and cylindrical bars, and circular plates under normal pressure. Some of the problems are analyzed with the elastic analog as basis, while others are based on a creep flow law formulated in terms similar to those of plastic flow. In all cases, exact and/or approximate solutions are presented for stresses and deformations.

Weight Control & Analysis

BOUNDS ON MINIMUM WEIGHT DESIGN. D. C. Drucker and R. T. Shield. Quart. Appl. Math., Oct., 1957, pp. 269-281. 12 refs. ONR-supported extension of a previously developed design procedure for elastic-perfectly plastic structures to provide upper and lower bounds on the minimum weight of three dimensional structures. The procedure is further specialized to one- and two-dimensional structures in which either direct or bending stresses are negligible. The generalization also includes the influence of body forces. In principle, therefore, such troublesome factors as the weight of the structure itself or centrifugal "forces" may be designed for in a direct manner. Radially symmetric plane stress and plate bending examples are solved to demonstrate direct design procedures.

WEIGHT-STRENGTH STUDIES OF STRUCTURES REPRESENTATIVE OF FUSELAGE CONSTRUCTION. J. P. Peterson. US, NACA TN 4114, Oct., 1957. 47 pp. 33 refs. Comparison of the ring-stiffened shell, the longitudinally stiffened shell, and shells constructed of waffle-like or sandwich-type plates in order to evaluate the effect of type of stiffening on bending strength. Shells of various materials are compared in order to evaluate the effect of material properties. The sandwich-type stiffening is found to be the most effective in terms of weight and strength. The ratio of compressive-yield stress to density of material is found to be the most important material parameter for sandwich-type shells. The density of the material is also important, especially in waffle-like or longitudinally stiffened shells. Further studies indicate that the bending strength of cylinders is significantly lowered by the presence of shear loads.

THERMODYNAMICS

METOD PROVERKI URAVNENIIA SOSTOIANIIA GAZOV PRI VYSOKOI TEMPERATURE. S. S. Semenov. AN SSSR Dokl., June 1, 1957, pp. 841-843. 13 refs. In Russian. Development of a method for checking the equation of state for gases at high temperatures in a shock tube, taking into account previous methods and results.

CONTRIBUTION A LA MESURE DES CHALEURS SPECIFIQUES DES GAZ ET DES VAPEURS. M. Huetz-Aubert. France, Min. de l'Air NT 68, 1957. 182 pp. 78 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 2,200. In French. Development of a method for determining thermodynamically the ratio of specific heats, based on the determination of coefficients of isothermic and isentropic compressibility. A harmonic oscillator acts as a piston to compress the gas adiabatically. The pressure-volume effects modify the natural frequency of the oscillator and by analyzing this effect the coefficient of isentropic compressibility can be deduced.

THE STATISTICAL THERMODYNAMICS OF MIXTURES OF LENNARD-JONES MOLECULES. I - RANDOM MIXTURES. II - DEVIATIONS FROM RANDOM MIXING. W. B. Brown. Royal Soc. (London) Philos. Trans., Ser. A, Oct. 17, 1957, pp. 175-246. 16 refs. Discussion of a development in the statistical theory of mixtures of spherical molecules. It is shown that for a mixture of molecules interacting according to the Lennard-Jones inverse-power potential, the assumption of random mixing is sufficient to relate the thermodynamic properties of the mixture exactly to those of a reference substance, after the manner of the law of corresponding states.

Combustion

STABILITY LIMITS AND BURNING VELOCITIES FOR SOME LAMINAR AND TURBULENT PROPANE AND HYDROGEN FLAMES AT REDUCED PRESSURE. Burton Fine. US, NACA TN 4031, Aug., 1957. 49 pp. 25 refs. Investigation of the effect of reduced pressure on blowoff, flashback, and burning velocities of propane-oxygen-nitrogen burner flames. The pressure exponent of burning velocity is nearly the same as for hydrogen-air flames and stability loops show the same blowoff and flashback characteristics as were previously observed for hydrogen-air flames. Of the two systems, the hydrogen-air system shows larger burning velocity, greater stability toward reduced pressure, and higher reaction order, as calculated from a simple thermal equation, while the propane-oxygen-nitrogen system shows the larger reactivity based on flashback.

FREE OSCILLATIONS OF A GAS IN AN ELASTIC CYLINDRICAL SHELL. H. V. Hahne. Lockheed Aircraft TN 2, LMSD-2160 (AFOSR TN 57-348) [AD 132421], Aug. 30, 1957. 28 pp. Theoretical investigation of the acoustic oscillations for a compressible gas contained in an elastic cylindrical shell. The mass and the elastic properties of the shell, as well as the coupling between the gas and the shell, are taken into account. Consideration is first given to the general case. Then the frequency equation is derived and the two special cases of purely tangential and of purely longitudinal modes are analyzed. Numerical results for the tangential modes are obtained for an assumed configuration, and are compared to those for an elastic shell in vacuum and for a rigid shell of analogous dimensions.

STUDY OF SOME BURNER CROSS-SECTION CHANGES THAT INCREASE SPACE-HEATING RATES. Appendix A, B - DERIVATION OF THE PRESSURE-DROP PARAMETER $\Delta P_{actual}/\Delta P_{1D}$. Appendix C - ESTIMATION OF PARAMETERS CONTROLLING BURNER PERFORMANCE. D. R. Boldman and P. L. Blackshear, Jr. US, NACA TN 4162, Nov., 1957. 38 pp. Study of the effect of area blockage on heat release using a two-dimensional glass-walled combustor fed with a homogeneous combustible mixture. The blockage of a single V-gutter flame holder is varied from 12.5% to 75% with negligible effect on combustion efficiency. When a small flame holder is used and a 62.5% restriction introduced downstream, the heat-release rate undergoes a three- to fourfold increase. Some effects of downstream blockage shapes are also given.

MESURE INSTANTANEE DES TEMPERATURES DE FLAMMES. A. Moutet. France, ONERA Pub. 88, 1957. 66 pp. 33 refs. In French. Description of basic methods for measuring flame temperatures by means of optical techniques, detailed study of a method of inversion of spectral bands, and discussion of its validity and possible improvements.

Heat Transfer

INVESTIGATION OF HEAT TRANSFER FROM A STATIONARY AND ROTATING CONICAL FOREBODY. R. S. Ruggeri and J. P. Lewis. US, NACA TN 4093, Oct., 1957. 30 pp. 12 refs. Test results indicating that the Nusselt-Reynolds Number relations provide good correlation of the heat-transfer data for the complete operating range at 0° angle of attack with and without spinner, and for 6° angle of attack with rotation. The experimental heat-transfer characteristics in the turbulent flow region were consistently in closer agreement with the results predicted for a two-dimensional body than with those predicted for a cone. The spinner-nose geometry appeared to cause early boundary-layer transition. Transition is initiated at a fairly constant Reynolds Number of 8.0×10^4, and is completed at Reynolds Numbers less than 5.0×10^5 for all conditions investigated.

Thermodynamic Properties

THERMODYNAMIC PROPERTIES OF AIR: TABLES AND GRAPHS DERIVED FROM THE BEATTIE-BRIDGEMAN EQUATION OF STATE ASSUMING VARIABLE SPECIFIC HEATS. R. E. Randall. USAF AEDC TR 57-8 [AD 135331], Aug., 1957. 82 pp. Presentation of thermodynamic properties and flow-process correction factors. The increase in the specific heats due to vibration of diatomic molecules is included by assuming the molecules to be perfect harmonic oscillators. The calculation procedures and the results of several calculations are included. These problems and results are for isotropic expansions and flow through normal shock waves.

VLIIANIE VNUTRENNEGO TERMICHESKOGO SOPROTIVLENIIA TELA NA TEPLOOBMEN. N. M. Karavaev and G. P. Stel'makh. AN SSSR Otd. Tekh. Nauk Izv., Feb., 1957, pp. 36-42. In Russian. Study of heat exchange between a real body and a flow of liquid and of the influence of internal thermal properties on the surface heat-exchange coefficient, as well as on the total heat-transfer coefficient.

VTOL & STOL

A REVIEW AND SUMMARY OF THE AVAILABLE AERODYNAMIC DATA ON DEFLECTED SLIPSTREAM ARRANGEMENTS SUITABLE FOR VTOL APPLICATIONS. J. A. Dunsby. Canada, NAE LR 205, Sept., 1957. 22 pp. 24 refs. Survey indicating that at the present time the NACA sliding flap arrangement is the most suitable, keeping in mind the low pitching moment requirements. Theoretical work is required to determine, if possible, the optimum airfoil shape and to provide an engineering method to estimate the characteristics of a deflected slipstream configuration. Further data are also required on the effect of chord/diameter ratio, particularly in the ground effect region.

STABILITY AND CONTROL CHARACTERISTICS OF THE VERTICAL ATTITUDE VTOL AIRCRAFT. E. R. Hinz. CAI-IAS Joint Meeting, Montreal, Oct. 21, 22, 1957, Preprint 763. 19 pp. 11 refs. Members, $0.50; nonmembers, $0.85. Presentation of aerodynamic characteristics at angles of attack above stall, and a discussion of their influence on flight in the transition regime. Maneuvering control criteria are analyzed to indicate requirements for the low speed regime, and it is shown how a reaction control system may be combined with aerodynamic control for low speed flight. Thrust control characteristics peculiar to hovering and transition flight are illustrated. Use of stability augmentation is discussed, and a comparison made with requirements of contemporary high performance aircraft.

PRELIMINARY WIND TUNNEL TESTS OF A LIFTING FAN IN A TWO-DIMENSIONAL AEROFOIL. Appendix A - INCOMPLETE DATA FOR OUTLET VANE TESTS. Appendix B - NOTE ON PREDICTION OF FAN DRAG FROM SIMPLE MOMENTUM THEORY. R. L. Wardlaw and R. J. Templin. Canada, NAE LR 207, Sept., 1957. 17 pp. Investigation of lifting fans mounted in an aircraft wing with their axes normal to the wing chord-plane. Results indicate that the highest lift increments due to the fan occur at high speeds, and that there is a minimum increment at small forward speeds. The drag increment due to the fan increases rapidly with increasing speed. The pitching moment increment has a maximum at low forward speeds, and the center of pressure of the fan lift shifts forward of the leading edge at these speeds.

EFFECT OF GROUND PROXIMITY ON THE AERODYNAMIC CHARACTERISTICS OF A FOUR-ENGINE VERTICAL-TAKE-OFF-AND-LANDING TRANSPORT-AIRPLANE MODEL WITH TILTING WING AND PROPELLERS. W. A. Newsom, Jr. US, NACA TN 4124, Oct., 1957. 15 pp. Tests with

the wing at an angle of incidence of 90°, the position used for vertical take-off or landing. With the model at various heights above the ground, the lift, drag, and pitching moment are measured and tuft studies are made to determine the flow field caused by the propeller slipstream. Data are obtained for the complete model, for the model with horizontal tail removed, and for the wing-propeller combination alone. Results of the investigation indicate that, when the model is hovering near the ground, there is a strong upwash in the plane of symmetry and also an increase in lift of about 10% of the propeller thrust. About one-half of this lift resulted from an increase in propeller thrust and one half resulted from an up load on the fuselage induced by the upwash. As the model approaches the ground, it also experiences an increasing nose-down pitching moment that evidently results from the up load on the fuselage, the rear part of which is longer than the front part. The addition of the horizontal tail which is located about halfway up the vertical tail does not increase the nose-down pitching moment because the fuselage decreases the energy of the upwash before it reaches the tail.

WATER-BORNE AIRCRAFT

EXPERIMENTAL AND THEORETICAL STUDIES OF HYDROFOIL CONFIGURATIONS IN REGULAR WAVES. Appendix A - WEINBLUM'S LINEARIZED EQUATIONS. Appendix B - CORRECTION FOR INERTIA OF TOWING ARM. Appendix C - SAMPLE CALCULATIONS OF HEAVE AND PITCH AMPLITUDE MAGNIFICATION AND HEAVE AND PITCH PHASE LAG FROM EXPERIMENTAL RECORDS. Patrick Leehey and J. M. Steele, Jr. US, Navy Dept., David Taylor Model Basin, Rep. 1140, Oct., 1957. 37 pp. Comparison of the experimentally measured and theoretically predicted values of the heave and pitch responses of area stabilized hydrofoil configurations to regular waves and to transient pulses. Curves of heave and pitch amplitude magnification and phase lag are given as functions of wavelength. The approximate linearized theory is found to give a qualitatively correct prediction of resonance and orbital motion effects. The theoretical amplitude magnifications are greater than the measured ones for most conditions, particularly for heave in following seas.

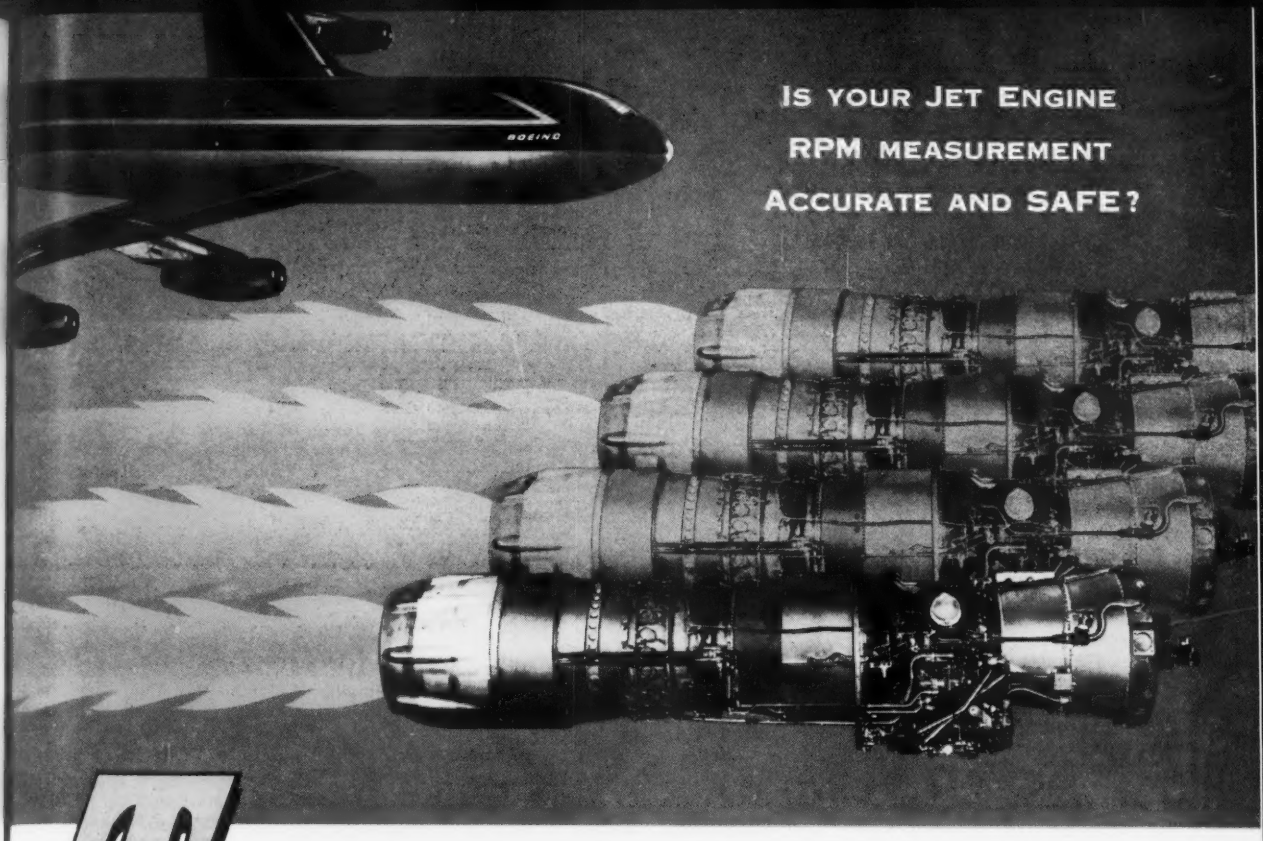
WIND TUNNELS & RESEARCH FACILITIES

THE AERODYNAMIC FORCES ON AN AEROFOIL IN NON-UNIFORM UNSTEADY MOTION IN A CLOSED TUNNEL. Appendix I - FORMS OF THE FUNCTION f(t). Appendix II - EVALUATION OF INTEGRALS INVOLVING ELLIPTIC AND ZETA FUNCTIONS. Appendix III - AN EXPRESSION FOR THE PRESSURE DISTRIBUTION. Appendix IV - TRANSFORMATION OF THE FUNCTION $T(\lambda, r)$. S. Rosenblat. Royal Soc. (London) Philos. Trans., Ser. A, Oct. 17, 1957, pp. 247-278. 12 refs. Analysis of the constraint due to walls which cause aerodynamic forces to assume values different from their free-stream values. Expressions are obtained for the pressure on the airfoil surface, and the lift and momentum about the mid-chord point. By a conformal transformation involving Jacobian elliptic functions the physical plane is mapped into a rectangle, and the theory is based on a solution of Laplace's equation satisfying certain given boundary conditions on this rectangle. The aerodynamic forces are expressed in terms of dimensionless "air-load coefficients", which are then compared with corresponding coefficients for an airfoil in an infinitely deep stream.

THEORETICAL ASPECTS OF THE CALIBRATION OF TRANSONIC TEST SECTIONS. S. B. Berndt. Sweden Flygtekniska Försöksanstalten, FFA Medd. 74 (Rep. 74), 1957. 28 pp. 14 refs. Application of the transonic similarity rule, together with the area rule, to calibration of the flow in a transonic test section. For longitudinal slots of constant width, it is shown that the proper slot setting will be the same for all models having similar flow fields in the sense of the transonic similarity rule. In general the upstream Mach Number in the test section, corresponding to sonic free-stream velocity, will not be exactly unity but somewhat smaller, the difference depending upon the size of the model.

A NOTE ON COMBUSTION DRIVEN SHOCK TUBES. Appendix - METHODS OF CALCULATION OF DETAILS OF COMBUSTION PROCESSES. G. A. Bird. Gt. Brit., RAE TN Aero. 2511, May, 1957. 18 pp. Application of the method of characteristics to a detailed study of the flow in a shock tube in which the high pressure gas is raised to a high temperature and pressure by combustion. A number of examples are considered in which the diaphragm is broken by the combustion process, which may be either a fast or slow combustion wave or a detonation wave. In all cases it is found that the resultant shock can have a higher speed than that produced by constant volume combustion but its velocity changes as it travels down the tube, and the flow between it and the contact surface is not uniform, even with friction and conduction effects neglected. It is concluded that, if it is desired to use the flow behind the shock as a short duration wind tunnel, constant volume combustion should be used.

INSTABILITY IN A SLOTTED WALL TUNNEL. J. L. King, P. Boyle, and J. B. Ogle. Gt. Brit., ARC CP 343, 1957. 24 pp. BIS, New York, $0.72. Description of investigations carried out in a 7-in. wind tunnel to examine in detail large pressure fluctuations observed in the working section of the A.R.L.'s new 30-in. water tunnel. Included are theoretical investigations which explain and describe the phenomena and which show that a jet of fluid, circular in cross section and moving through the same fluid, is unstable. The slotted wall is unable to stabilize all frequencies of disturbance. The length of the working section determines the preferred wavelengths of disturbance, which, in turn, feed energy back to the upstream end of the jet by compressing the fluid in the reservoir surrounding the working section. In the absence of a reservoir, the instability disappears.



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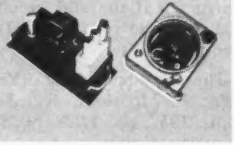

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Boeing Designs 707 Structure for Long Fatigue Life. Irwin Stambler. *Av. Age*, Aug., 1957, pp. 26–33 ff. Discussion of fail-safe techniques applied to the new jet air liner.

Special Issue: Britain's Aircraft Industry. *Flight*, Aug. 30, 1957, pp. 293–340. Survey of civil and military aircraft, engines, and missiles.

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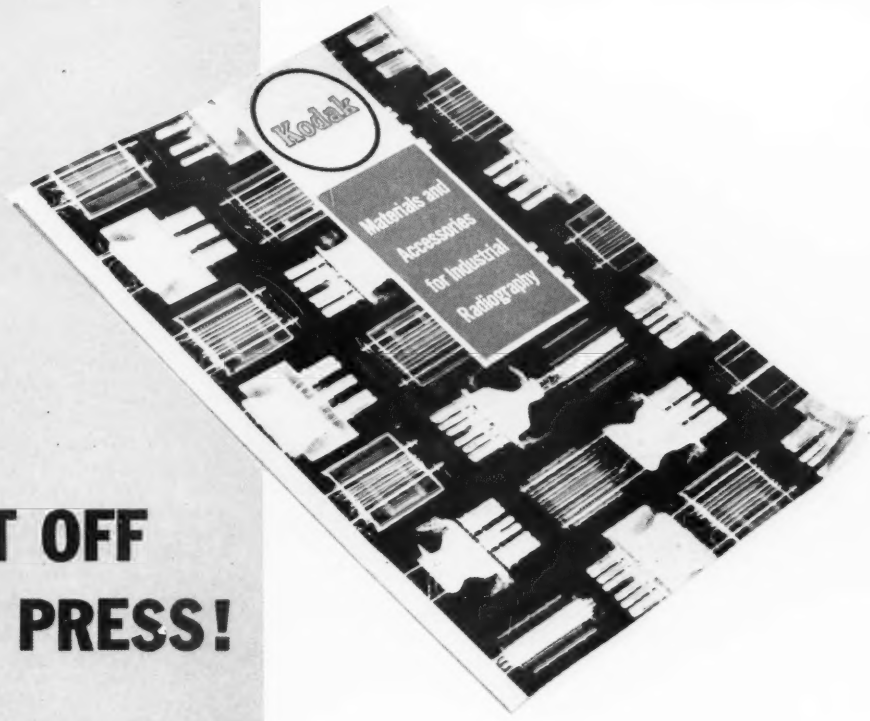

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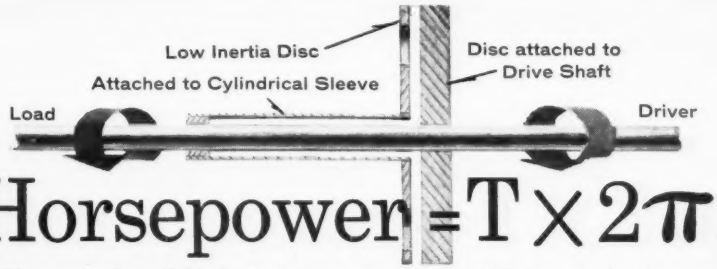

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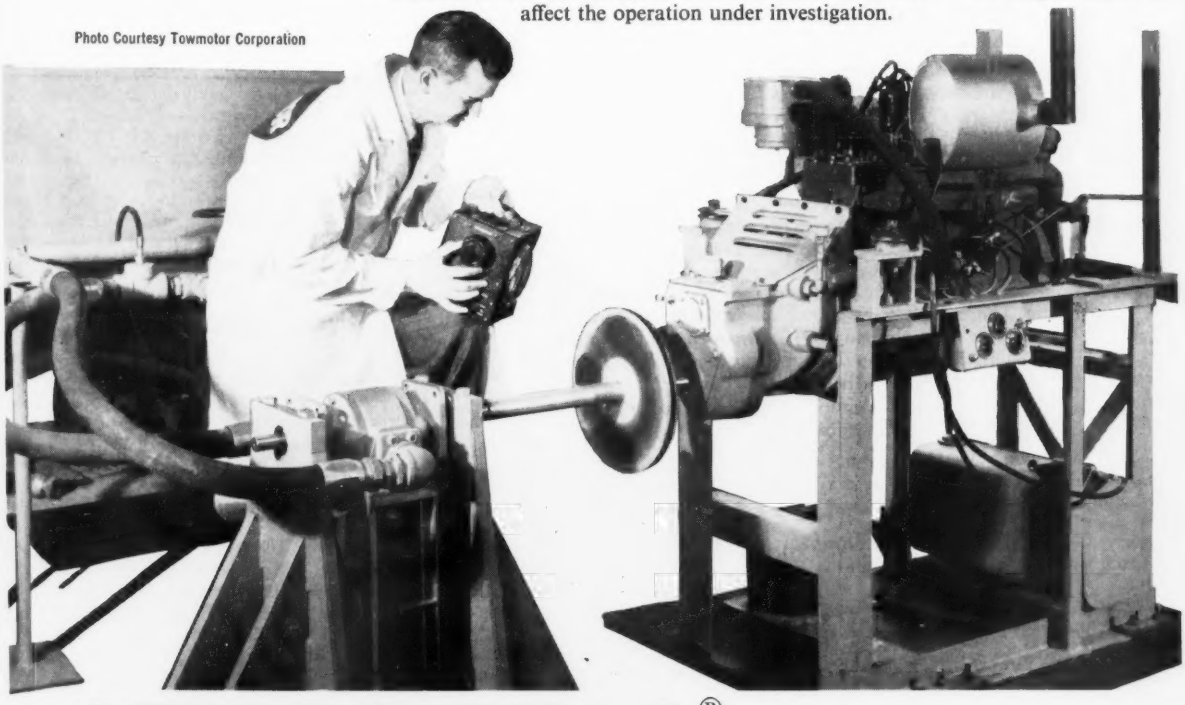

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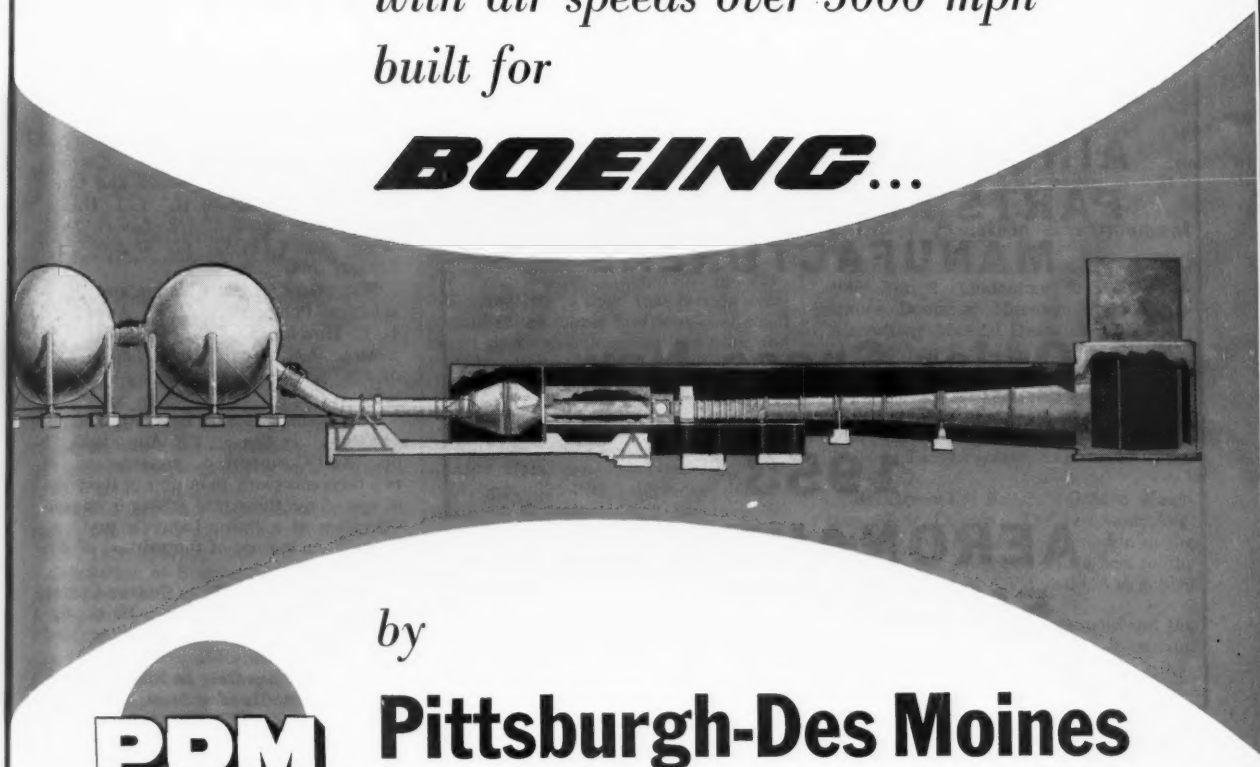

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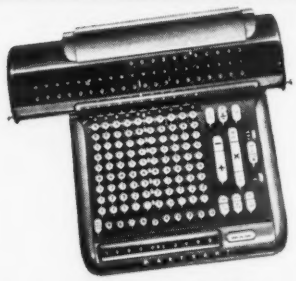
Waldes Truarc Rings speed assembly, facilitate maintenance, improve performance of new automatic calculator



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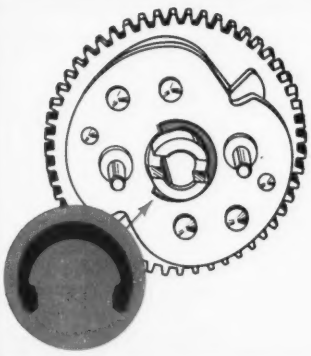
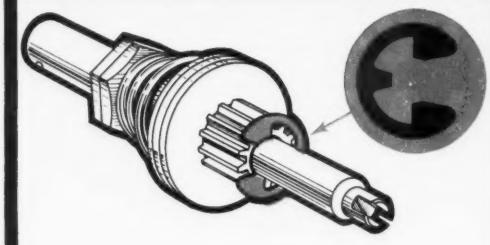
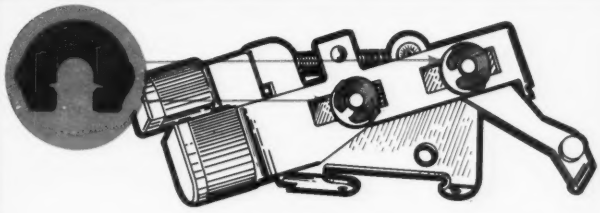
automatic-decimals calculator made by Marchant Calculators, Inc., Oakland, California.



CRESCENT RING SPEEDS ASSEMBLY, DISASSEMBLY
Main clutch utilizes radially-installed series 5103 crescent ring for rapid assembly and disassembly. Ring's low protruding shoulder provides necessary clearance between ring and the two studs. The main clutch operates each time a Deci-Magic control key is depressed.



E-RING SECURES PARTS AGAINST SPRING THRUST. Slip clutch assembly uses Truarc series 5133 E-ring to hold parts on shaft. Functioning of the assembly is dependent upon the ring's ability to withstand thrust exerted by the heavy barrel spring.



LOCKING PRONG RINGS PERMIT SIMPLE DESIGN. Shift slide assembly uses two Truarc series 5139 bowed locking prong rings to lock the parts together in a sliding fit. Precise amount of spring tension prevents objectionable wobble and noise, permits the key to slide smoothly in operation. Easy radial assembly and disassembly of rings facilitates field maintenance and repair. Alternative construction would have required cut washer, spring washer and hairpin-type spring clip on each stud.

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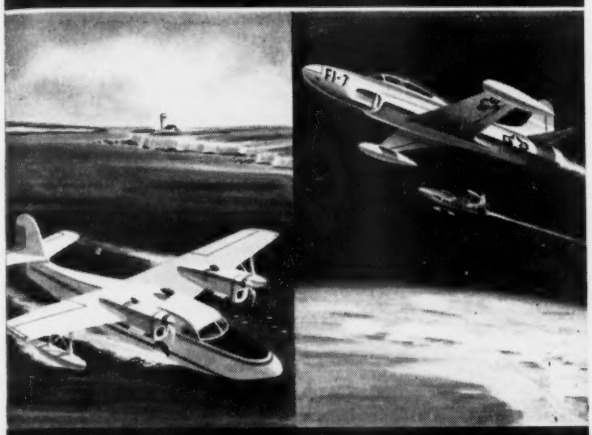

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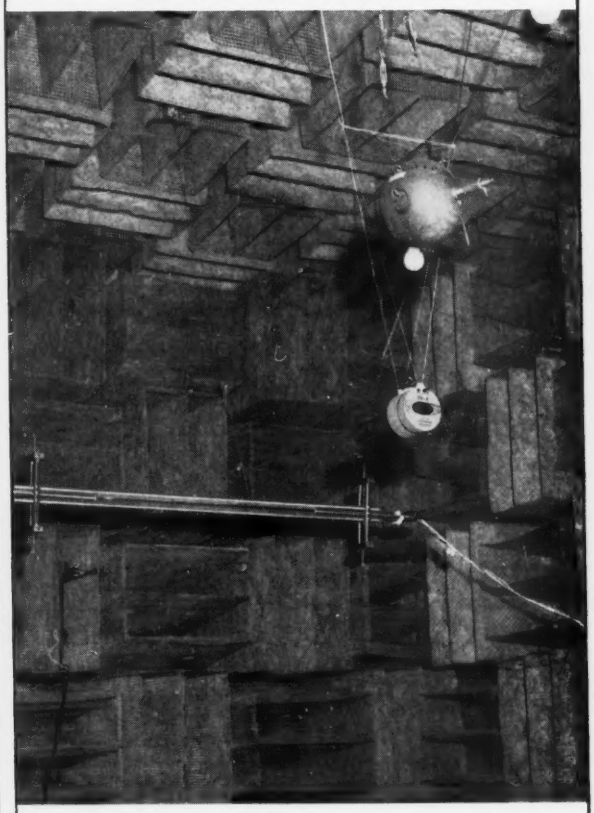

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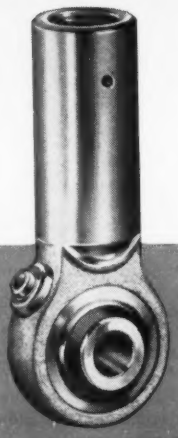

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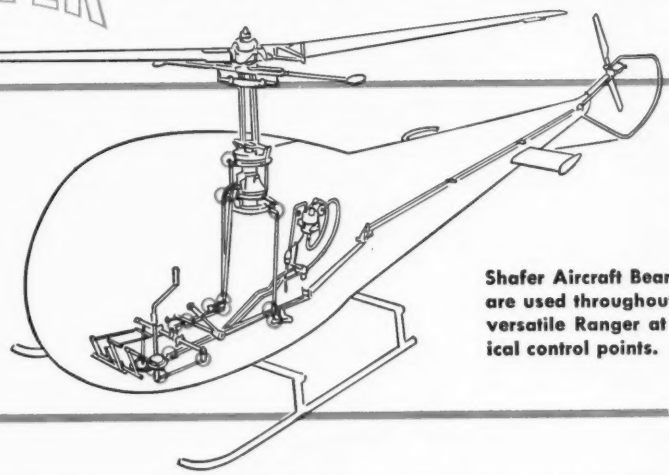

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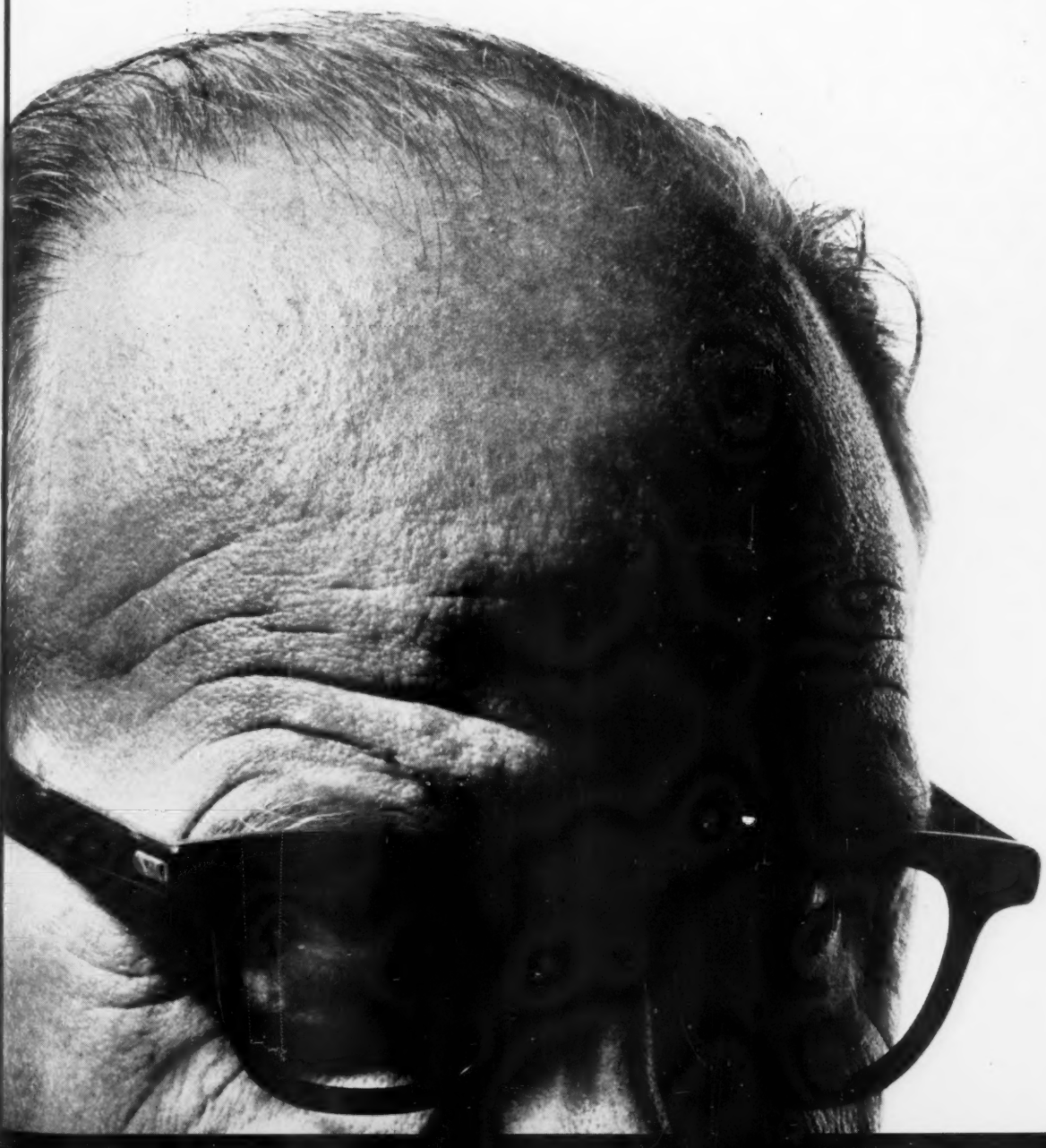

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Evolution of the Vertijet. *Ryan Reporter*, Aug. 16, 1957, pp. 3–15. Discussion of the four phases in the development of the Ryan X-13 Vertijet, the new VTOL aircraft, and of its Washington flight test. The four developmental steps include (1) test vehicle, (2) horizontal flight, (3) vertical flight, and (4) transition and hover.

Jet-Powered VTOL X-14. Charles Williams. *Am. Helicopter*, Aug., 1957, p. 11.

Ryan X-13 Vertijet. Frank Coleman. *Am. Helicopter*, Aug., 1957, pp. 8, 9. Description and principle of operation.

Wind Tunnels & Research Facilities

Properties of Test Section Walls with Longitudinal Slots in Curved Flow for Subsonic and Supersonic Velocities (Theoretical Investigations). Bernhard H. Goethert. *USAF AEDC TN 55–56 [AD 131406]*, Aug., 1957. 23 pp. Derivation of mathematical expressions for the boundary conditions of longitudinally slotted walls. A relationship is first established for the effect of flow curvature on the boundary conditions in the vicinity of conventional slotted walls for incompressible flow. This relationship is then extended to include the influences of protruding slots as well as perforated cover plates at the base of the slots.

The 10 cm x 15 cm Supersonic Wind Tunnel of the Department of Aeronautics, University of Tokyo. Tomijiro Moriya, Jiro Kondo, Akira Takano, and Takashi Tani. *Japan Soc. Aero. Eng. J.*, Aug., 1957, pp. 209–214. In Japanese.

The Variable Density High Speed Cascade Wind Tunnel of the Deutsche Forschungsanstalt für Luftfahrt, Braunschweig. H. Schlichting. *NATO AGARD Rep. 91*, Feb., 1956. 5 pp. Brief description of the new open-jet type tunnel with a Mach Number range from 0.2 to 1.1.

Development of the R. A. E. 6 Inch Diameter Shock Tube. I Bursting of Diaphragms at 200 Atmospheres. S. G. Cox. *Gt. Brit., RAE TN Aero.2510*, May, 1956. 12 pp. Experiments using a test rig to investigate the problem of providing a diaphragm for the RAE high-temperature shock tube. A successful method is developed which involves clamping the diaphragm with a free piston and sealing with O-rings.

Longitudinal Airplane Dynamics Wind Tunnel Test Equipment. O. B. Tufts, G. R. Duryea, Jr., R. C. MacArthur, and A. H. Zimmerman. *USAF WADC TR 55–184 [AD 112452]*, July, 1956. 230 pp. 16 refs. Discussion of the design and construction of equipment for making longitudinal dynamic stability tests in a wind tunnel. The equipment includes a flexible oscillator-support, a calibration model airplane, and instrumentation.

New Method of Flow Visualization for Low-Density Wind Tunnels. R. A. Evans. (*California U., Inst. Eng. Res. TR HE-150-119*, June, 1954.) *J. Appl. Phys.*, Sept., 1957, pp. 1,005–1,010. WADC-sponsored description of a technique involving the absorption by oxygen of radiation in the wavelength region 1,400 A to 1,500 A.

Suspension Magnétique d'une Maquette en Soufflerie. M. Tournier and P. Laurenceau. *La Recherche Aéronautique*, July-Aug., 1957, pp. 21–26. In French. Development of a method for mounting wind-tunnel models.

Some Comments on High-Lift Testing in Wind Tunnels with Particular Reference to Jet-Blowing Models. A. Anscombe and J. Williams. *RAeS J.*, Aug. 529–540. Discussion of special problems in model testing which arise when high-lift applications are involved. Comments are made on factors controlling model size, on test rigs and methods of feeding air to models without applying constraints to the balance, and on the measurement of jet-flow parameters.

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Aerothermodynamic Staff members discuss heat flux during reentry of a hypersonic vehicle. Left to right: J. I. Osborne, aerodynamics; R. G. Wilson, thermodynamic research; W. E. Brandt, thermodynamic analysis; Dr. L. H. Wilson, Thermodynamic Section head.

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Aeronautical Reviews — BOOKS

AERONAUTICS, GENERAL

Proceedings of the Second European Aeronautical Congress, Scheveningen, September 25–29, 1956, Vol. 1. Amsterdam, Netherlands Society of Aeronautical Engineers, % Nationaal Luchtvaartlaboratorium, 1957. 503 pp., illus., diagrs. 25 guilders.

The *Proceedings* of the *Second Congress* have resulted in three volumes of papers, lectures, and short communications that encompass varied fields in aeronautics. The 80 articles making up the set are photo-offset prints of all but 15 of the original texts and are in the language of the original: French, German, or English. Volumes 2 and 3 will be covered in a subsequent issue of the REVIEW.

Contents: Opening Addresses, P. A. van de Velde, H. C. van Meerten, and J. Algera. A Proposal for a More Exact Definition of the Factor of Safety as Applied to Aircraft Structures (In English), G. Aldinio. Turbojet Transport in Civil Aviation (In English), I. A. Aler, K.L.M. The N. L. L. Transonic Tunnel (In English), B. J. van Asselt. Analytic Study of Spin, Using Data Obtained with a Horizontal Tunnel, and a Method of Testing Models in Free Air (In French), E. Bazzocchi. Some Results of Swedish Research on Wings and Airfoils (In German), H. Behrbohm. Measurements of the Unsteady Aerodynamic Forces on a Wing with Control Surfaces (In English), H. Bergh. An Electrical Control System for Aviation Turbines; The Use of Magnetic Amplifiers (In French), J. Beslier. Flight Measurements during Performance Check Tests of a Commercial Jet Aircraft—Caravelle (In French), R. Beteille. Evolutionary Trends of Turbojets Used in Civil Aviation (In French), J. Blanc. "Voltabloc" Batteries for Starting Aircraft Turbines (In French), M. Bougaran. The Hydraulic Analogy in Experimental Aerodynamics (In French), B. Bozinovitch. The Industrial Facilities for Aerodynamic Experimentation of A.I.C.M.A. (In French), J. Brocard. A Study of the Vibration of Turbomachine Blades (In French), Brouée. On the Influence of the Prandtl Rule on the Calculation of Forces Excited by a Helicopter Rotor (In German), G. Brüning. Lift Distribution of Wings Limited by Plates (In French), A. Castells. Contribution to the Practical Calculation of Compressible Flow in Axial Turbines, Taking into Account the Radial Variation of Inlet Temperature and Friction (In German), G. Cordes. The Influence of Rounding-Off Errors in Calculation of Eigenvalues of Matrices by Iteration (In English), H. J. Dannenburg. Measurement Techniques with Multiple Recorders Using Photographic Paper (In French), P. Devergne. The Aerodynamics of Jet Engines Mounted at the Rear of the Fuselage (In French), M. Duguet. The "Atar Volant" and its Future (In French), G. Eggers. Managerial and Technological Aspects of Aircraft Production (In English), E. van Emden. On the First Jet Engines: a Review of Their Development (In German), W. Encke. Jet Engines and Airports (In English), J. Fernández-Amigo. The Influence of Local Buckling on the Primary Failure of Stiffened Panels Loaded in Compression (In English), G. J. Fonk. Tests of Hot Water Aspirators for High Powered Wind Tunnels (In French), O. Frenzl. Contraction Brittleness in Commercial Aluminum-Copper-Zinc-Magnesium Alloys (In French), J. A. García Poggio and J. Sáenz Insausti. Development of Visual Landing Aids for High-Performance Aircraft (In English), S. J. Gerathewohl. Calculation, Tabulation and Uses of Some Functions Occurring in the Theory of the Conical Disc Subjected to Centrifugal and Thermic Stresses (In English), R. Giovannozzi.

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AUTOMATIC CONTROL

Analytical Design of Linear Feedback Controls. George C. Newton, Jr., Leonard A. Gould, and James F. Kaiser. New York, John Wiley & Sons, Inc., 1957. 419 pp., diagrs. $12.

Analytical design as described in the present volume is the design of control systems by application of the methods of mathematical analysis to idealized models which represent physical equipment. The starting point is system specifications which include descriptions of the input, the disturbances, and the response desired. The design objective is to minimize (or maximize) the chosen performance index which is used as the basis for judging the system performance. Included is a comprehensive discussion of the analytical design procedure for two performance indices. For systems subject to transient input signals, the integral-square error is used as a performance index. For stochastic input signals, the mean-square error is used. Although the book was originally planned as a monograph on analytical design theory, the authors, all of the Massachusetts Institute of Technology, have made it useful to graduate students by including four appendixes which review Fourier and Laplace transforms, the application of the theory of functions to the problem of stability determination, the gain-phase plane methods of trial-and-error design, and other methods of trial-and-error design. A table of special integrals needed in applying analytical design theory to practical problems and a discussion of the gain-phase relationship for minimum-phase transfer functions constitute two other appendixes.

CHEMISTRY

Handbook of Chemical Data. Edited by F. W. Atack. New York, Reinhold Publishing Corporation, 1957. 629 pp., tables. $6.75.

A successor to Vol. 1 of the *Chemists' Year Book*, this convenient, pocket-size handbook dispenses with unwieldy references and charts to present a vast array of facts constantly needed by the active chemist. By virtue of its clear, relevant tables of physical constants and properties, the book is exactly what the title states.

Contents: (1) Atomic Weights. (2) Physico-Chemical Constants. (3) Solubilities. (4) Refractive Indices. (5) Dissociation Constants. (6) Refractive Index Liquids. (7) Properties of Minerals. (8) Inorganic Compounds. (9) Organic Compounds. (10) Qualitative Analysis. (11) Volumetric Analysis. (12) Factors for Quantitative Analysis. (13) Conversion Table for Weights and Measures. (14) Tables for Interconversion of Thermometric Scales. (15) Hydrometric Tables. (16) 5-Figure Logarithms. (17) Powers of Numbers. (18) Sines and Tangents. (19) Mensuration Formulae. (20) Mechanical Constants and their Logarithms.

COMPUTERS

Proceedings of the Third Annual Computer Applications Symposium, Chicago, October 9–10, 1956. Sponsored by Armour Research Foundation, Illinois Institute of Technology. Chicago, The Foundation, 1957. 148 pp., illus., diagrs., tables. $3.00.

The trend toward more effective and widespread use of medium-scale digital computers is evident from the program of this symposium which was held to exchange ideas and experiences of users in both science and industry. Fourteen papers presented at the meeting serve to illustrate the diversity of computing machines and their applications as existing today.

Contents: (1) Development of a Products Pipe Line Simulator on an NCR 102A. (2) Application of the IBM 650 to Stock Brokerage Operations. (3) The ELECOM 125 in Personnel Classification Research. (4) The Election and the UNIVAC. (5) Programming the DATATRON for Ordinary Life Insurance Operations. (6) Manufacturing Data Processing on the IBM 650. (7) The UNIVAC FILE-COMPUTER Applied to General Accounting Functions. (8) Solution of Rotating Electric Machinery Problems with ALWAC. (9) The IBM 650 Applied to Problems of the Electrical Industry. (10) The NCR 120A as an Aid in Training and Research. (11) Model Making Problems in Election Forecasting. (12) Optical Calculations Using the Burroughs E 101. (13) Use of the DATATRON in Petroleum Engineering. (14) Research Calculations on the READIX Computer.

DOCUMENTATION

Scientific and Technical Translating and Other Aspects of the Language Problem. UNESCO. Paris, UNESCO; New York, Columbia University Press, 1957. 282 pp., diagrs., tables. $4.00.

The introduction to Chapter 1 of this UNESCO report states that at least 50 per cent of scientific literature is in languages which more than half the world's scientists cannot read. Thus, disregarding qualitative differences, the greater part of what is published is inaccessible to most of those who could benefit from it. The report, the result of a resolution adopted at the General Conference of UNESCO in 1952 and 1954, is a statement of progress in dealing with the general problem of enabling scientists to exploit knowledge

published in languages other than their own. It discusses the ramifications of the loss of knowledge through the language barrier and points out the extent to which the situation can be improved by available solutions: translations; increasing in scientists the ability to read foreign languages; encouraging the publishing of scientific literature in languages that are widely known; and promoting publications in an easily learned international auxiliary language.

ENGINEERS

Career Satisfactions of Professional Engineers in Industry. A Research Survey for the Professional Engineers Conference Board for Industry, in Cooperation with the National Society of Professional Engineers; Developed by Opinion Research Corporation, Princeton, N.J. Washington, Professional Engineers Conference Board for Industry, 1957. 84 pp., diagrs., tables. $3.00.

Based on interviews with a sampling of professional engineers in industry, this report summarizes the thinking of engineers at three different stages of professional experience—3 to 6 years, 10 to 15 years, and 20 to 25 years. In all, eleven companies were included in the survey in the following industries: aircraft, automobile manufacturing, chemical, electronics, electrical machinery, heavy equipment, petroleum refining, and rubber.

Contents: About the Survey. The Research Plan. Research Findings: (1) The Engineers in this Survey. (2) Career Outlook of Professional Engineers. (3) Satisfaction and Frustration on the Job. (4) The Question of Professional Status. (5) Are the Values of the More Successful Engineer Different from the Others? (6) Summary and Implications. Detailed Survey Tabulations. About the Tables. Appendix Tables.

FLUID MECHANICS

An Introduction to Fluid Mechanics and Heat Transfer; With Applications in Chemical & Mechanical Process Engineering. J. M. Kay. Cambridge, England, At The University Press; New York, Cambridge University Press, 1957. 309 pp., diagrs. $7.00.

The main emphasis in this text, which is suitable for use in university courses, is on fundamental principles. Intended especially for the chemical and mechanical engineer, the principles, wherever possible, are related to actual engineering problems. Among the topics presented are the fundamentals of fluid flow, viscosity, heat conduction, diffusion, energy and momentum principles, dimensional analysis, equations of fluid motion and forced convection, turbulence, compressible flow in pipes, solid particles in fluid flow, flow through packed beds, pumps, compressors, heat exchangers, and condensation and evaporation. Dr. Kay, Professor of Nuclear Power, University of London, has based his text on lectures given in the Department of Chemical Engineering while he was at Cambridge from 1948–1952.

HELIUM

The Physical and Thermodynamic Properties of Helium. Jesse T. Simmons. (Technical Report No. D-9027.) Los Angeles, Wm. R. Whittaker Co., July 1, 1957. 79 pp., diagrs., tables. $10.

This report is a brief summary of currently available information, presented in both tabular and diagrammatic form, on the flow characteristics and the physical and thermodynamic properties of gaseous helium, encompassing the pressure range of 14.7 to 6,000 psia and the temperature range of $-440°$ to 600°F. The properties covered include: gas constant R, density, specific volume, compressibility factor, entropy, enthalpy, specific heat at constant pressure and constant volume, ratio of C_p/C_v, viscosity, thermal conductivity, sonic properties, and diffusion and permeability.

MATERIALS

Behaviour of Metals at Elevated Temperatures; Lectures Delivered at the Institution of Metallurgists Refresher Course, 1956. London, Iliffe & Sons, Ltd.; N.Y., Philosophical Library, 1957. 122 pp., illus., diagrs., tables. $6.00.

The present volume contains four papers that consider the effects of temperatures on metals from only slightly above normal up to the highest working limits. *The Engineering Properties of Metals at High Temperatures,* by N. P. Allen, covers such properties as stability, elastic constants and coefficients of expansion, resistance to plastic deformation and fracture under stress, behavior under fluctuating temperatures, and resistance to chemical attack. *The Effect of Temperatures up to 450°C on Metals,* by G. Meikle, gives particular emphasis to airframe structures and guided missiles and includes a discussion of kinetic heating. *Non-Ferrous High-Temperature Materials,* by L. B. Pfeil, considers the attempts to provide improved materials at temperatures of 500°C. and up. *High-Temperature Steels,* by W. E. Bardgett, explains how research leads to better composition of steels for specific tasks.

Thermochemical Data of Alloys. O. Kubaschewski and J. A. Catterall. London, New York, Pergamon Press, 1956. 200 pp., tables. $7.50.

The monograph presents all the relevant data necessary to establish the "free-energy diagrams" of metallic systems, and of the oxides, sulphides, nitrides, phosphides, and carbides of the transition metals. The assessment of the thermodynamic data—i.e., the partial and integral heats, entropies, and free energies—is different from previous compilations of the data on theoretical metallurgy in that it deals with solutions and homogeneity ranges, rather than with stoichiometric compounds. A total of nearly 230 binary and ternary systems has been considered, for many of which the available information is still incomplete. Critical values are given for every system, followed by a brief discussion of their origin and of the mode of calculation. Density changes on alloying are also tabulated. The authors are with the National Physical Laboratory.

Brittle Behavior of Engineering Structures. Earl R. Parker. (Prepared for the Ship Structure Committee under the General Direction of the Committee on Ship Steel, National Academy of Sciences—National Research Council.) New York, John Wiley & Sons, Inc., 1957. 323 pp., illus., diagrs., tables. $6.00.

Written for the purpose of summarizing the available information on the brittle behavior of steel in engineering structures, this book contains a discussion of the theories and mechanism of failure, a review of test methods used for evaluating relative brittleness, interpretations and summaries of test results, a discussion of the effects of welding and composition variations on notch toughness, and a report of service failures. The author is Professor of Metallurgy and Chairman, Division of Mineral Technology, University of California.

Engineering Properties and Applications of Plastics. Gilbert Ford Kinney. New York, John Wiley & Sons, Inc., 1957. 278 pp., diagrs., tables. $6.75.

The emphasis in this book is on the fundamental characteristics of plastics, the newest of the engineering materials. Separate chapters are devoted to fabrication methods, and to the mechanical, electrical, optical, thermal, and chemical properties displayed by a large variety of organic plastics. The author, Professor of Chemical Engineering, U.S. Naval Postgraduate School, discusses, in order of increasing complexity, polyethylene, polyvinyl chloride, polystyrene, the acrylic plastics, various vinyl-type plastics, the cellulose plastics, phenolic plastics, the amino plastics, polyesters, polyamides, expoxies, silicones, and rubbers. A unified treatment of subject matter, rather than a topical approach, permits the principles, concepts, and terminology established in the simpler cases to be utilized in treatment of the more complex materials.

Rubber; Fundamentals of its Science and Technology. Jean Le Bras. Translated from the French by Irene E. Berck. New York, Chemical Publishing Co., Inc., 1957. 464 pp., illus., diagrs. $12.

The first American edition of this work which was published in France in 1951 and again in 1953 contains much information and many new photographs not included in the earlier editions. It is written for the rubber chemist and technologist seeking the latest developments in rubber chemistry and physics, theories of elasticity, vulcanization, accelerators, reinforcement, antioxidants, etc., and the most up-to-date procedures of rubber technology and testing. Complicated theoretical considerations have in general been avoided, although certain important aspects, such as the chemical structure of rubber, are discussed in great detail. Special attention is given to the principles of selecting the most suitable compounding ingredients to meet the specifications placed on finished chemical products. Dr. Le Bras is General Scientific Inspector of the French Rubber Institute and the Institute of Rubber Research in Indo-China.

MATHEMATICS

Spheroidal Wave Functions. Carson Flammer. Stanford, Calif., Stanford University Press, 1957. 220 pp., diagrs., tables. $8.50.

Addressed to the applied mathematician, the mathematical physicist, and the mathematical engineer rather than to the pure mathematician, this Stanford Research Institute monograph is intended to facilitate the use and calculation of prolate and oblate spheroidal wave functions by the presentation of a detailed and unified account of the currently known properties of these functions. The text, which is accompanied by 135 pages of tables of numerical values, contains a historical survey of the development of the functions and a survey of the many diverse physical problems to which the functions have been applied. All known expansions and representations of the angle and radial spheroidal functions are derived and discussed. Power series expressions for the eigenvalues and expansion coefficients are given in the tables. The tables also contain numerical values of the eigenvalues and expansion coefficients as well as some numerical values of the functions themselves. The author is Senior Mathematical Physicist, Stanford Research Institute.

Vector Spaces and Matrices. Robert M. Thrall and Leonard Tornheim. New York, John Wiley & Sons, Inc., 1957. 318 pp. $6.75.

The wide range of applications of vector spaces and matrices both inside and outside of pure mathematics has led to the development of the subject at many different levels. In this text, designed for a 1-year course in college-level mathematics, the authors have chosen to proceed simultaneously at two levels—concretely via matrices, and intrinsically via linear transformations. This dual approach introduces the student to the power of mathematical reasoning based on a set of axioms, yet does not neglect concrete formulations which are extremely important to the beginner.

Contents: (1) Vector Spaces. (2) Linear Transformations and Matrices. (3) Systems of Linear Equations. (4) Determinants. (5) Equivalence Relations and Canonical Forms. (6) Functions of Vectors. (7) Orthogonal and Unitary Equivalence. (8) Structure of Polynomial Rings. (9) Equivalence of Matrices over a Ring. (10) Similarity of Matrices. (11) Linear Inequalities.

A Dictionary of Statistical Terms. Maurice G. Kendall and William R. Buckland. (Prepared for the International Statistical Institute with the Assistance of UNESCO.) London, Oliver and Boyd; New York, Hafner Publishing Company, 1957. 493 pp. $4.50.

Approximately 2,000 terms essential to the science of statistics appear in this work. The criterion for the selection of a term was that of

current usage, whether intrinsically desirable or not, while the validity of the definition was verified by experts in the fields to which the terms related. An attempt has been made to keep notation and usage of terms consistent without simultaneously standardizing the symbolism or nomenclature. A number of terms currently used in foreign languages, without English equivalents or with a different literal meaning, have been included as part of the main body of the dictionary. The dictionary, which is written in English, includes complete glossaries in French, German, Italian, and Spanish.

NUCLEAR ENERGY

Nuclear Power Reactors. Edited by James K. Pickard. (The Geneva Series on the Peaceful Uses of Atomic Energy; Edited by James G. Beckerley.) Princeton, N.J., D. Van Nostrand Company, Inc., 1957. 388 pp., illus., diagrs., tables. $8.50.

Based on the more significant papers delivered at the Geneva Conference, the fourth volume in this series is limited to reactors as a source of heat for electric-power production. Extensive coverage is given to water-moderated reactors, such as the pressurized and boiling water types since it is generally believed that they hold the best promise of providing practical atomic power for the next 10 to 15 years. Less space is given to the liquid-metal-cooled, homogeneous, fast breeder, and other types of reactors. Other topics given consideration are the rising world need for power and the capability of nuclear power to fill this need; the problems of procuring, processing, and handling uranium fuel materials; and the need to lower the overall cost of the power produced. A bibliography of papers from the Geneva Conference is included as an appendix to the text.

PHYSICS

Solid State Physics: Advances in Research and Applications, Vol. 4. Edited by Frederick Seitz and David Turnbull. New York, Academic Press, Inc., 1957. 540 pp., illus., diagrs., tables $12.

Since the appearance of Vol. 1 of this series, research activity in the field of solid-state physics has continued to increase rapidly; in view of this, the editors have considered it advisable to continue the initial policy of publishing two volumes a year that will offer articles of three general types: (1) broad elementary surveys that have particular value in orienting the advanced graduate student or an investigator having little previous knowledge of the subject; (2) broad surveys of fields of advanced research that serve to inform and stimulate the more experienced investigators; (3) more specialized articles describing important new techniques, both experimental and theoretical. Volume 4 contains two articles which are considerably longer than the average contemplated by the editors; however, the special nature of the topics made it desirable to publish the articles in the somewhat extended form.

Contents: (1) Ferroelectrics and Antiferroelectrics, Werner Kanzig. (2) Theory of Mobility of Electrons in Solids, Frank J. Blatt. (3) The Orthogonalized Plane-Wave Method, Truman O. Woodruff. (4) Bibliography of Atomic Wave Functions, Robert S. Knox. (5) Techniques of Zone Melting and Crystal Growing, W. G. Pfann.

Introduction to Electrical Applied Physics. N. F. Astbury. New York, Philosophical Library, 1957. 241 pp., diagrs. $10.

During the past 25 years or so, electrical science has developed in such a way that a new subject, which the author chooses to call electrical applied physics, has revived interest in and applications of earlier work which has seemed to be of academic interest only. The present work is an essay in which an attempt is made to bring together the classical bases of the subject and the elements of some specialist topics which, by the natural processes of technological evolution, are finding their way into all fields of applied science. The subject discussed include electrical and magnetic fields and circuits, circuit components and

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measurements, electromechanical and electroacoustical systems, electron devices, and electromagnetic waves and radiation. The necessary mathematics and algebra are presented in conjunction with the relevant problem under discussion, while algebraic and vector methods are used simultaneously as the work dictates. The author is Professor of Physics, University of Khartoum.

POWER PLANTS

Aircraft Engines of the World, 1957. Paul H. Wilkinson. Washington, Paul H. Wilkinson, 734 15th St., N.W., 1957. 320 pp., illus., diagrs., tables. $15.

The fifteenth annual edition of this standard work has been completely rewritten to ensure uniform standardization throughout and contains power-plant information that is current as of July, 1957. Among the new features this year is a section on nuclear aircraft engines in which Government and private research in this field is described and nuclear propulsive systems are explained. The turbojets and turboprops (main power plants) section now occupies 164 pages and contains descriptions of 92 engines, of which 18 are new. Specifications are also given for ramjets, rocket-jets, and specialized gas turbines, as well as a substantial number of new reciprocating engines and new models of those already in service, including those designed for helicopters. The accessories and equipment section presents many of the latest aviation products of the United States and Great Britain. Fuel and lubricating oil tabulations have been revised and for the first time include ram-jet and rocket-jet fuels. In the section on aircraft and their engines, the author has supplied six up-to-date tabulations of leading military and civil types, including gas-turbine air liners currently in service or undergoing test.

RADIO ASTRONOMY

Radio Astronomy; International Astronomical Union Symposium No. 4. Held at the Jodrell Bank Experimental Station Near Manchester, August, 1955. Edited by H. C. van de Hulst. Cambridge, England; New York, Cambridge University Press, 1957. 409 pp., illus., diagrs., tables. $9.50.

The proceedings of the symposium, as recorded in this volume, include 80 papers on various aspects of radio astronomy, among which are contributions from research groups in Australia, Czechoslovakia, England, Finland, France, Germany, Japan, the Netherlands, Switzerland, the United States, and the Soviet Union. Many of the papers have been improved as a result of discussion at the symposium or by the inclusion of data not available in August, 1955. Six main lines of investigation are reported: spectral line investigations; point sources; galactic structure and statistical studies of point sources; the quiet sun; the active sun; and meteors and planets. Introductory papers on these topics summarize the state of knowledge prior to the symposium. Radio telescopes and other technical subjects are not treated in separate papers, but novel instruments like the Mills' Cross antenna and new-receiver developments are described along with the first results obtained.

SPACE TRAVEL

Proceedings; The Age of Space. A Non-Technical Conference on Missiles, Rockets, and Space Travel—and Their Impact on Our Times, May 16, 1957. Sponsored by Southern Research Institute. Birmingham, Ala., The Institute, 1957. 43 pp., illus., diagrs.

Contents: (1) U.S. and Russian Missile Technology, Erik Bergaust. (2) A Trip to Mars, Ernst Stuhlinger. (3) Beyond the Sky with Rocket Power, Dan A. Kimball. (4) Metals for Space Travel, F. L. LaQue. (5) People for Space Vehicles; Space Medicine, Dan C. Ogle. (6) The Earth Satellite Program, John P. Hagen. (7) Military and Civilian Research, C. C. Furnas.

THERMODYNAMICS

Combustion Researches and Reviews, 1957. (NATO AGARD AGARDograph No. 15.) London, Butterworths Scientific Publications; New York, Interscience Publishers, Inc., 1957. 204 pp., illus., diagrs., tables. 40*s*. $5.60.

The principal subjects discussed at the tenth AGARD Combustion Panel meeting in Oslo, Norway, during May, 1956, were pulse-jets, shock-tube techniques, and high-pressure combustion. This second volume of *AGARD Combustion Researches and Reviews* contains ten papers, of which five were presented at Oslo and the balance were voluntarily submitted to the Panel during the past year. Future volumes in this series will appear approximately every 2 years.

Contents: (1) Stationary Flames at Pressures Above One Atmosphere, G. A. McD. Cummings. (2) Hydrogen-Halogen Flames, R. C. Anderson. (3) Flame-Spreading Characteristics in Combustion, N. R. L. Maccallum. (4) Etude de la Flamme des Mélanges Air-Kérosene (Study of Flames in Air-Kerosene Mixtures), J. Rappeneau. (5) Bubble-Points, Flammability Limits and Flash-Points of Petroleum Products, B. P. Mullins. (6) A Theoretical Analysis of Reaction Rate Controlled System—Part 1, M. V. Herbert. (7) Remarques sur les Pulsoréacteurs (Remarks on Pulse-Jets), J. Ducarme. (8) Quelques Résultats Obtenu a la S.N.E.C.M.A. dans l'Etude des Pulsoreacteurs (Some Results Obtained by S.N.E.C.M.A. in the Study of Pulse-Jets), J. Bertin and B. Salmon. (9) An Introduction to the Use of the Shock Tube for the Determination of Physico-Chemical Parameters, S. S. Penner, F. Harshbarger, and V. Vali. (10) An Outline of a Method for Preparing Enthalpy Charts for Dissociating Gas Mixtures in the Temperature Range 600° to 4,000°K., O. Lutz.

Elements of Heat Transfer. Max Jakob and George A. Hawkins. 3rd Ed. New York, John Wiley & Sons, Inc., 1957. 317 pp., illus., diagrs., tables. $6.75.

Basic principles of heat transfer and the applications of those principles to simple problems are the major items dealt with in this book that was originally published as *Elements of Heat Transfer and Insulation*. The present edition retains the writing style of earlier editions but features these changes in subject matter: a new table on thermal conductivity of liquid metals; an added section on the use of equivalent circuits for the solution of problems; information on one type of thermal analyzer; additional material on the analysis of engineering systems; new sections on the heating of liquid metals in turbulent flow through pipes, hydrodynamic and thermal boundary layers, convective heat transfer at high velocities, and the analogy between electrical and thermal circuits for convective heat transfer; a new section on heat exchanger effectiveness ratio; an expanded chapter on heat transfer in condensing and boiling, to include the differences between nucleate, partial film, and film boiling; a concise section on gas radiation; new coverage of mass transfer and the similarity between heat and mass transfer; and up-to-date references and problems (increased by 25 per cent).

Thermodynamics of Heat-Power Systems. F. W. Hutchinson. Reading, Mass., Addison-Wesley Publishing Company, Inc. 490 pp., diagrs., tables. $8.50.

The present treatment of thermodynamics is based on 20 years of teaching experience and reflects the author's belief that emphasis should be on ideas rather than on equations. His intent is to provide a descriptive core of fundamental principles and concepts that will enable the lecturer to use this background as a base for excursions into the realms of qualification, exception, and extension. Also he propounds a logical thermodynamic chain that progressively investigates energy as it relates to: source, storage, liberation, transition, transformation, transportation, and utilization. Wherever possible, the technical material is developed in terms of a generalized equation or a generalized example; this procedure is particularly to be noticed in the sections on combustion analysis and general energy equations and in the analysis of a comprehensive reverse cycle.

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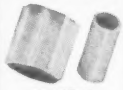

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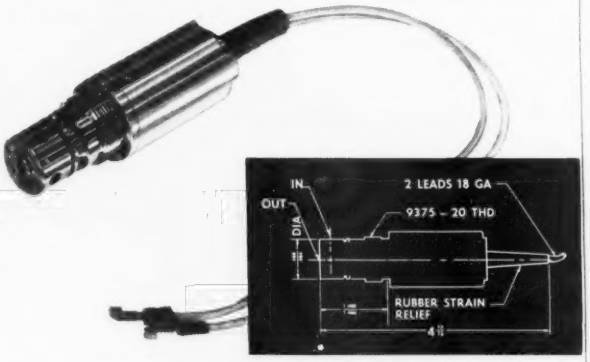

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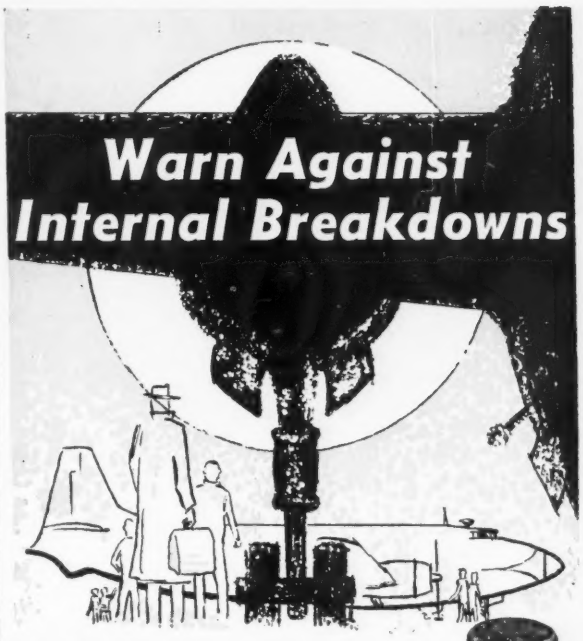

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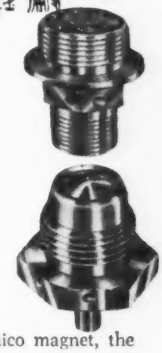

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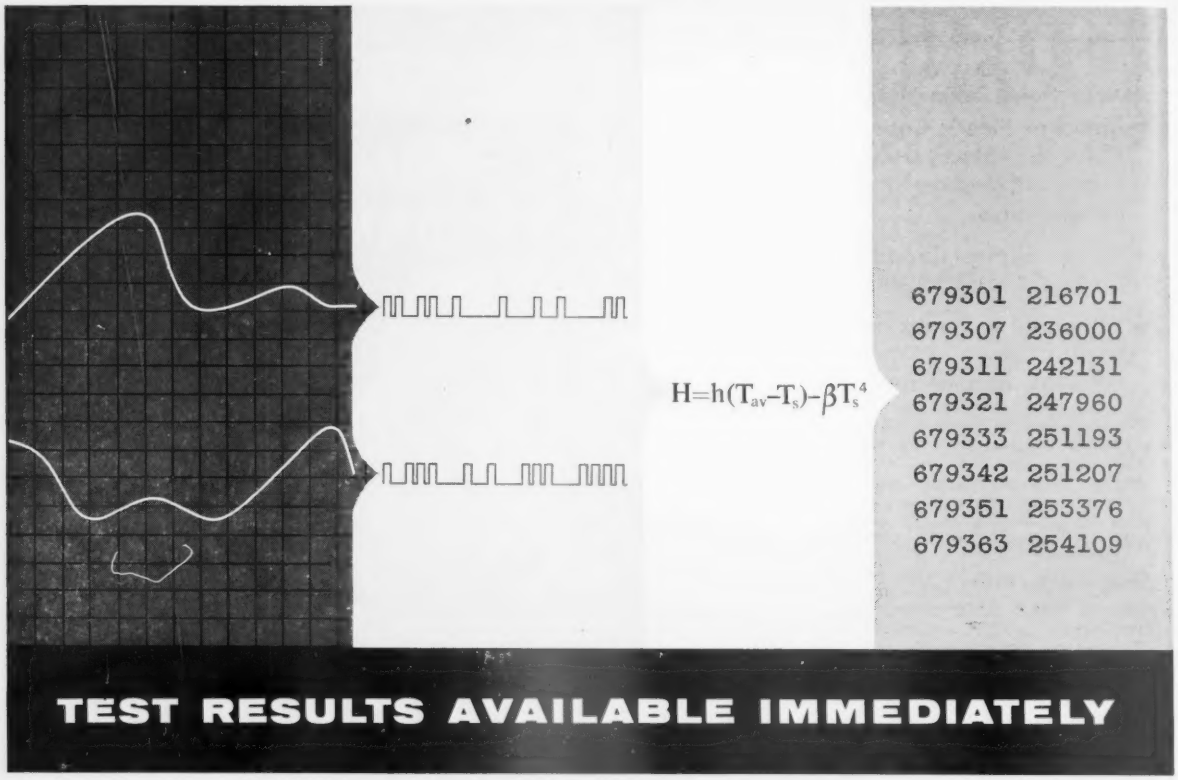

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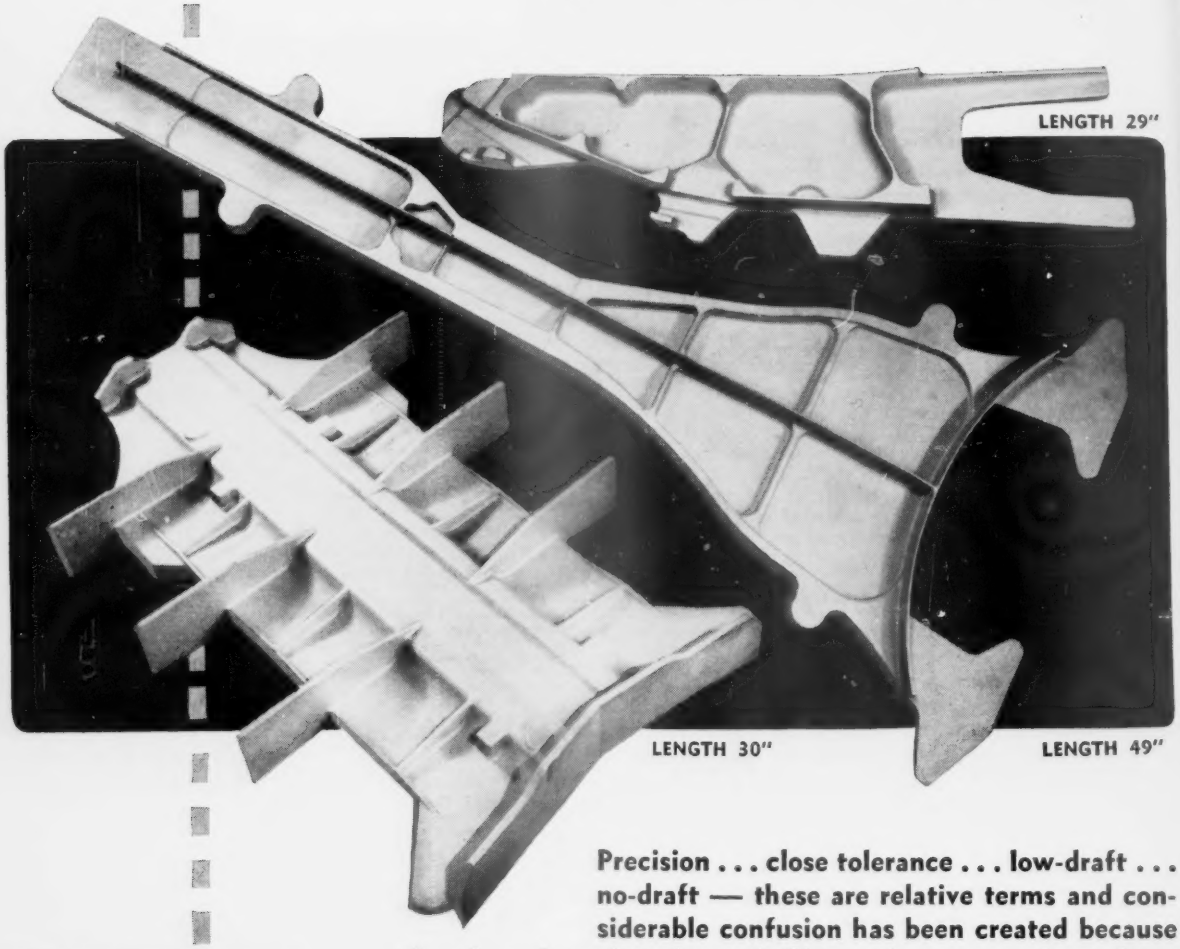

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"What's New With Lithium." Monthly newsletter contains information on lithium and its compounds. *American Lithium Institute, Inc.*, 32 Nassau St., P.O. Box 549, Princeton, N.J.

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Sprayed-On Textured Coating for Missiles. Contains mica, asbestos, and perlite which combined with an elastic chemical base provides insulation and protection over a wide range of temperatures without losing its bond or flexibility. *Kenitex Chemicals Inc.*, 2950 S. Fairfax Ave., Los Angeles, Calif.

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"Titanium Prices." Pocket-sized technical booklet, "Titanium Minute Reader No. 1," is the first of a continuing series. *Titanium Metals Corp. of America*, 233 Broadway, New York 7, N.Y.

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"Pet" Solid Propellant Rocket Motor. This 0.6-lb. motor is 1.5 in. in diameter and 4.75 in. long; furnishes 40 lbs. of thrust for 1 sec. *Atlantic Research Corp.*, Alexandria, Va.

Fast-Acting Electrochemical Squib Switches. 4-page fact sheet gives physical and electrical characteristics. *Atlas Powder Co.*, Parke Thompson Ordnance Section, 9404 Watson Rd., St. Louis 19, Mo.

Aircraft Cables & Assemblies. New brochure includes tables showing engineering data on different cable constructions. *Bergen Wire Rope Co.*, Gregg St., Lodi, N.J.

Machmeter & True Air-Speed Meter. This pressure-actuated electromechanical instrument responds to inputs of static pressure, pitot pressure, and stagnation temperature. *M. Ten Bosch, Inc.*, Pleasantville, N.Y.

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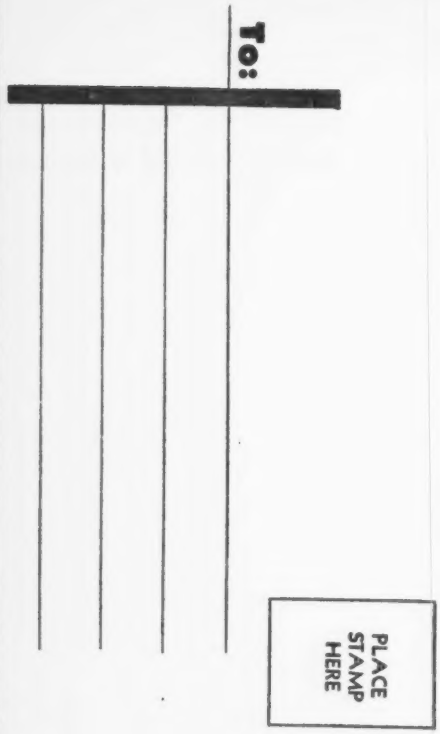

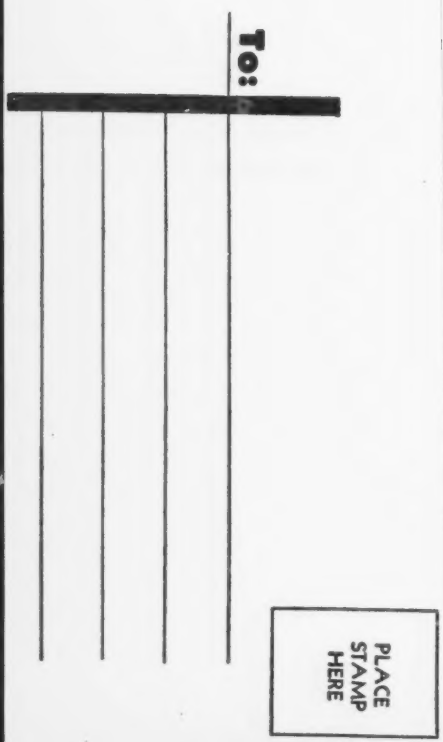

dom from contact flutter under environmental conditions. *Burton Mfg. Co.*, Colorado Ave. at 26th St., Santa Monica, Calif.

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Tapered Orifice Valve. Function is basically that of a needle valve, but, by concentrating all of the flow area in one triangular section instead of around an annular ring, it is virtually clogproof. *General-American Valve Co.*, P.O. Box 444, Corona Del Mar, Calif.

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Miniature Precision Ball Bearings. 24-page catalog describes standard radial miniature bearings ranging in size from 1/10 to 3/8 in. o.d. *Miniature Precision Bearings, Inc.*, Keene, N.H.

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"Power-Safe" Electric Brakes. 36-page technical report WEB 6293 includes photographs, drawings, diagrams, and complete data on units designed for fail-safe applications. *Warner Electric Brake & Clutch Co.*, Beloit, Wis.

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Time Delay Relays & Sequence Program Switches. Developed to meet all the varied requirements of sequence programing; offer up to six load circuits in the repeat-cycle timer and up to five load circuits in the reset-cycle unit. *Automatic Timing & Controls, Inc.*, King of Prussia, Pa.

Subminiature Automatic Calibrating Bridge-Balancing System. For use with strain gages, accelerometers, pressure, position, or any other resistance-type transducers to control, balance, and automatically calibrate up to 24 transducer channels. *B & F Instruments, Inc.*, 4732 N. Broad St., Philadelphia 41, Pa.

Transistor Replacement Chart. Gives information about the correct Bendix transistor to use when replacing weak or burned out transistors. *Bendix Red Bank Div.*, Long Branch, N.J.

Type 1006 Wide Range Pulse Generator. Technical bulletin discusses unit producing a stable source of pulses in eight overlapping frequency ranges up to 4.5 mc. *Burroughs Corp.*, 1209 Vine St., Philadelphia 7, Pa.

S9-4 Hi-Temp Switch Features Ceramic Case. Provides precision tolerances in an ambient temperature range of −100° to +900°F. *Electro Snap Switch & Mfg. Co.*, 4218 W. Lake St., Chicago 24, Ill.

Custom-Built D.C. Power Supplies. Bulletin GEA-6690 describes tailor-made systems for computer, aircraft, and special applications. *General Electric Co.*, Schenectady 5, N.Y.

Hermetically Sealed Miniature Precision Switch. Unaffected by ambient pressures; a balancing system automatically equalizes environmental pressures on the actuating mechanism. *Haydon Switch, Inc.*, Waterbury 20, Conn.

Type 1231 High Power Telemetering Diplexers. These instruments feed signals from two 100-watt transmitters into a single-missile antenna system. *Hycon Eastern, Inc.*, 75 Cambridge Parkway, Cambridge 42, Mass.

Transistorized Frequency Converter. Designed for application with auto-pilot systems, guidance systems, and in telemetering functions, as a source of high-frequency power for magnetic amplifiers; transistorized circuitry said to reduce weight and overall size by approximately 60 per cent. *Robertshaw-Fulton Controls Co.*, 401 N. Manchester, Anaheim, Calif.

Instrumentation Cables for Telemetering & Data Recording. 8-page technical bulletin gives complete data. *Rome Cable Corp.*, Rome, N.Y.

Miniature Permanent-Magnet Motors. Feature a rotatable brush holder which is adjustable for best commutation and power output; write for data sheet No. 2857. *Servo-Tek Products Co.*, 1086 Goffle Rd., Hawthorne, N.J.

"Radio Web" Air Navigation & Traffic Control System. Designed to provide a nonsaturable envelope for traffic control, accurate navigation anywhere within the web, and a feature for the prevention of air-collision. *Stavid Engineering, Inc.*, U.S. Highway 22, Plainfield, N.J.

Transistorized 200-Watt Transmitter. Claimed to increase substantially the effective range of FM/FM telemetering; stepped up transmission power overrides background noise near the terminal phase of missile flights. *Texas Instruments Incorporated*, 6000 Lemmon Ave., Dallas 9, Tex.

"Dynox 95" Miniature High Voltage Solid-State Battery. Capable of delivering high current drains for long periods of time; can supply a steady current of 1 by 10^{-9} amp. for 176,000 hours at 70°F. with only a 10 per cent voltage drop, or a flash current of 20 microamp. *Universal Winding Co.*, Patterson Moos Div., 90-28 Van Wyck Expressway, Jamaica 18, N.Y.

Model W1801 Servo Repeater System. Includes a transistorized servoamplifier, motor, synchro, power supply, and gear train, all in a housing 2 in. in diameter by 4 in. long; total weight 12 oz. *Waldorf Instrument Co.*, Wolf Hill Rd., Dix Hills, Huntington Station, N.Y.

DRAFTING ROOM, PRODUCTION, & MISC. EQUIPMENT

Bi-Axial Stretch-Former. This new two-way stretch-forming machine is for use in forming integrally stiffened missile skins; can accommodate sheet sizes up to 5 by 24 ft. *The Hufford Corp.*, 1700 E. Grand Ave., El Segundo, Calif.

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Analog to Digital Converter. Type 525 Encoder is designed to provide precise conversion of analog input data to digital output voltages. *ACF Industries, Inc.*, Avion Div., 800 N. Pitt St., Alexandria, Va.

"Hydrauliscope." An electronic analyzer utilizing oscilloscopic principles to measure pressure activity and phenomena in operation of hydraulic systems; camera attachments are available to make permanent records of hydraulic activity. *Aeroquip Corp.*, Jackson, Mich.

Temperature-Altitude-Humidity Walk-In Test Chamber. For simulating flight testing of electronic components; outfitted with a vibrator on tracks which allows in-the-chamber specimen vibration simultaneously with temperature and altitude testing. *American Research Corp.*, Farmington, Conn.

Friction Torque Tester for Instrument Antifriction Ball Bearings. Operates by slowly rotating the outer race of a bearing under test; tester explores the various configurations of the bearing and gives precise measurements of starting friction torque on a chart recorder; overall accuracy at full range is better than ±2 per cent. *Asch Equipment Co.*, 642 Keowee St., Dayton 4, Ohio.

SR-4 Foil-Type Rosette Strain Gages. Feature substantially higher sensitivity and stability; can withstand temperatures to 300°F. in continuous service. *Baldwin-Lima-Hamilton Corp.*, Waltham 54, Mass.

All-Transistor Analog-to-Digital Converter. 4-page brochure contains complete specifications and utilizes basic circuit diagrams and sketches to explain operation. *Beckman Instruments, Inc.*, 325 N. Muller Ave., Anaheim, Calif.

"Dynamaster" X-Y Recorder. This new strip-chart recorder will automatically plot a continuous curve showing the relationship of one measured variable to another. *The Bristol Co.*, Waterbury 20, Conn.

Event Recorder. Instantly and simultaneously records up to 100 channels of on-off information in permanent chart record form; valuable in checking electrical and electronic sequences in missile and aircraft control systems. *Brush Instruments*, 3405 Perkins Ave., Cleveland 14, Ohio.

HY-6000 Dynamic Shock Testing Device. Produces extremely high loads instantaneously with thrusts up to 40,000 lbs. *Consolidated Electrodynamics Corp.*, 1775 Mt. Read Blvd., Rochester 3, N.Y.

Type 4-120 Vibration Pickup. Developed for ground and in-flight monitoring of jet engines; can also be used in all high-frequency, low-amplitude vibration studies under extremes of temperature. *Consolidated Electrodynamics Corp.*, 300 N. Sierra Madre Villa, Pasadena, Calif.

Seven-Channel Magnetic Tape Recording Head for Missiles. Can be directly connected to thermocouples to record without the use of amplifiers, using only 20 microwatts. *Data Storage Devices Co.*, 7828 Burnet Ave., Van Nuys, Calif.

Air-Borne Time Code Generator. Employing transistor-driven magnetic cores, this lightweight 1½-cu.ft. unit is designed for missile and aircraft instrumentation; supplies a 16-bit, 24-hour binary code to hours, minutes, and seconds. *Electronic Engineering Co. of Calif.*, 1601 E. Chestnut Ave., Santa Ana, Calif.

70-Mm. Camera Designed for Missile Tracking. The large frame, 2¼ in. sq., minimizes tracking error and helps keep high-speed, elusive missiles in sight. *Flight Research, Inc.*, Richmond, Va.

Model B386 Angular Oscillating Table. Designed primarily to evaluate the damping and response characteristics of angular accelerometers and rate gyros. *Genisco, Inc.*, 2233 Federal Ave., Los Angeles 64, Calif.

Mach 1.5 Total Temperature Probe. Features ceramic-blanketed temperature element; measures stagnation temperature over the range of −70° to +350°C. *G. M. Giannini & Co., Inc.*, 918 E. Green St., Pasadena 1, Calif.

SLM Differential Pressure Indicator. Model DPI-114 measures both fast and slow transient differential pressures at any two points in a pneumatic or hydraulic system; can be calibrated by conventional static methods. *Kistler Instrument Corp.*, 15 Webster St., N. Tonawanda, N.Y.

Model 2249 Gyro Drift Recorder. Capable of detecting, indicating, and recording with extreme accuracy the minute increments of drift characteristic of modern high-precision gyros. *Lear, Inc.*, 3171 S. Bundy Dr., Santa Monica, Calif.

Air-Hydraulic Aircraft Test Stands. Adaptable for both hydrostatic and functional testing; reciprocating demand type pumps deliver hydraulic fluid under pressure as required. *Ledeen Mfg. Co.*, 3350 N. Gilman Rd., El Monte, Calif.

Magnetic Tapes for Instrumentation Recording. 8-page booklet covers six types of "Scotch" brand tapes for use in telemetering, air-borne recording, and other instrumentation applications. *Minnesota Mining & Mfg. Co.*, 900 Bush St., St. Paul 6, Minn.

BCT-300 Transistor Curve Tracer. 4-page bulletin #387C includes a block diagram showing the variety and flexibility of test functions. *Norden-Ketay Corp.*, Commerce Rd., Stamford, Conn.

Portable Air-Speed & Altitude Field Test Set. For flight line testing of aircraft pressure instruments and systems; self-contained unit weighs only 85 lbs. *Norden-Ketay Corp.*, Commerce Rd., Stamford, Conn.

Model AAc-2 Angular Acceleration Generator. Data sheet S-120 describes this torsional pendulum instrument applicable to the evaluation of effects in several planes on moving coil instruments and small electrodynamic devices. *Statham Development Corp.*, 12411 W. Olympic Blvd., Los Angeles 64, Calif.

"Hydrashaker" Vibration Excitation System. Claimed capable of providing previously unattainable combinations of force, acceleration, and frequency. *Wyle Associates*, 128 Maryland St., El Segundo, Calif.

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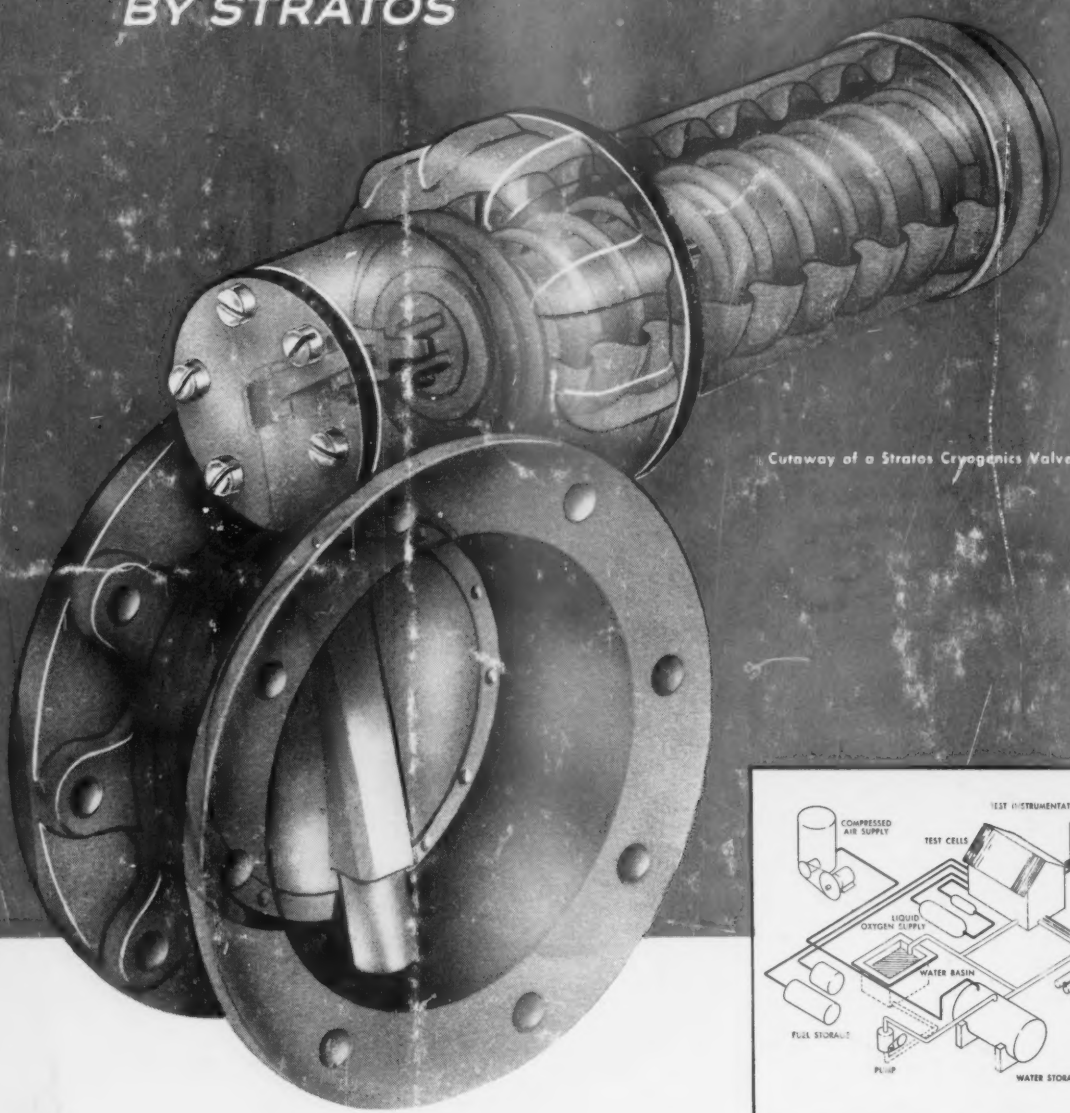
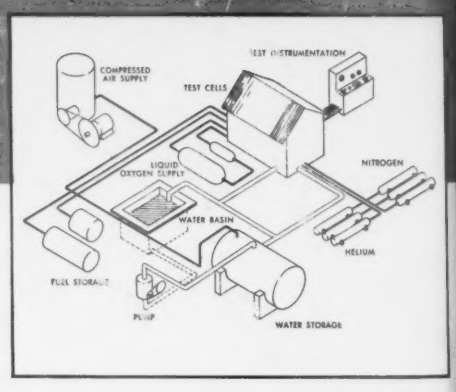


Cutaway of a Stratos Cryogenics Valve



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